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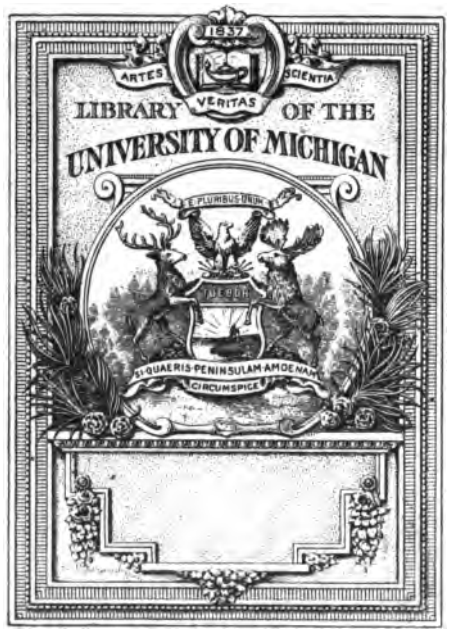
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PROCEEDINGS

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OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

TWENTIETH MEETING,

HELD AT

INDIANAPOLIS, INDIANA,

AUGUST, 1871.

CAMBRIDGE:
PUBLISHED BY JOSEPH LOVERING.
1872.

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AT

THE INDIANAPOLIS MEETING.

ASA GRAY, *President.*
GEORGE F. BARKER, *Vice-President.*
JOSEPH LOVERING, *Permanent Secretary.*
F. W. PUTNAM, *General Secretary.*
W. S. VAUX, *Treasurer.*

STANDING COMMITTEE.

EX-OFFICIO.

ASA GRAY,
G. F. BARKER,
JOSEPH LOVERING,
F. W. PUTNAM,
T. S. HUNT,
C. F. HARTT,
W. S. VAUX.

AS CHAIRMEN OF THE SECTIONAL COMMITTEES.

J. L. SMITH,
G. C. SWALLOW.

FROM THE ASSOCIATION AT LARGE.

E. J. COX,
JAMES HALL,
J. E. HILGARD,
I. A. LAPHAM,
J. L. SMITH,
ALEXANDER WINCHELL.

LOCAL COMMITTEE.

DANIEL MACAULEY, *Chairman.*
THOMAS MCINTIRE, *First Vice-Chairman.*
JOHN C. WRIGHT, *Second Vice-Chairman.*
T. B. ELLIOTT, *General Secretary.*
E. J. COX, *Corresponding Secretary.*
F. V. W. DAVIS, *Treasurer.*

E. S. ALVORD,
FIELDING BEELER,
W. A. BELL,
A. R. BENTON,
J. BERNARD,
D. M. BERRY,
J. J. BINGHAM,
JAMES BRADEN,
WILLIAM BRADEN,
R. J. BRIGHT,
A. H. BROWN,
R. J. BROWN,
VALENTINE BUTSCH,
W. W. BUTTERFIELD,
JOHN W. BYRKIT,
W. B. CHAMBERLAIN,
JOHN COBURN,
JOHN COLLETT,
J. A. COMINGERE,
ROBERT CONNELLY,
THOMAS COTTRELL,
CARLOS DICKSON,
NORMAN B. EDDY,
H. A. EDSON,
JOHN R. ELDER,
W. H. ENGLISH,
JOHN FISHBACK,
W. P. FISHBACK,
E. T. FLETCHER,
S. FLETCHER, Jr.,
W. B. FLETCHER,
BENJAMIN FRANKLIN,
ALLEN FURNAS,
EDWARD C. GARLICK,
J. M. GASTON,
DAVID GIBSON,
L. W. HASSELMAN,
J. A. HENDRICKS,
B. C. HOBBS,
ISAAC HODGSON,
JOHN H. HOLLIDAY,
MILTON B. HOPKINS,
P. G. C. HUNT,
N. A. HYDE,
NATHAN KIMBALL,
EDWARD KING,
THOMAS D. KINGAN,
M. M. LANDIS,
M. G. LEE,
G. M. LEVETTE,
ERIE LOCKE,
JOHN M. LORD,
DAVID MACY,
V. T. MALOTT,
NICHOLAS MCCARTY,
J. E. MCDONALD,
GEORGE MERRITT,
J. A. MORRIS,
JOHN W. MURPHY,
JOHN C. NEW,
F. S. NEWCOMER,
JOHN S. NEWMAN,
W. H. L. NOBLE,
W. R. NORFSINGER,
CHARLES B. PARKMAN,
THEOPHILUS PARVIN,
J. A. PERKINS,
S. E. PERKINS,
WINSLOW S. PIERCE,
JOSEPH POOLE,
A. G. PORTER,
DILLARD RICKETTS,
A. L. ROACHE,
FREDERICK P. RUSH,
JAMES B. RYAN,
G. A. SCHMITT,
HORACE SCOTT,
A. SEIDENSTICKER,
THOMAS H. SHARPE,
J. C. SHOEMAKER,
A. C. SHORTRIDGE,
J. E. SIMPSON,
GEORGE W. SLOAN,
JOHN S. SPANN,
THADDEUS M. STEVENS,
J. GEORGE STILZ,
WILLIAM H. WEEKS,
WILLIAM D. WILES,
J. H. WOODBURN.

OFFICERS OF THE SECTIONS.

SECTION A.

J. L. SMITH, *Chairman.* JOHN N. STOCKWELL, *Secretary.*

Sectional Committee.

E. B. ELLIOTT, S. D. TILLMAN, F. H. VAN DER WEYDE.

SECTION B.

G. C. SWALLOW, *Chairman.* J. H. EMERTON, *Secretary.*

Sectional Committee.

E. D. COPE, E. S. MORSE, OLIVER MARCY.

SUB-SECTION C OF SECTION A.

J. E. HILGARD, *Chairman.* W. W. BUTTERFIELD, *Secretary.*

Sectional Committee.

R. H. WARD, A. H. TUTTLE, EDWIN BICKNELL.

SPECIAL COMMITTEES.

A. Committees continued from former Meetings.

1. *Committee to report in Relation to Uniform Standards in Weights, Measures, and Coinage.*

F. A. P. Barnard,
John F. Frazer,
Wolcott Gibbs,
B. A. Gould,
Joseph Henry,
J. E. Hilgard,
John LeConte,
H. A. Newton,
Benjamin Peirce,
W. B. Rogers,
J. L. Smith,
John Torrey.

B. New Committees.

1. *Committee to audit the Accounts of the Permanent Secretary and the Treasurer.*

H. L. Eustis,
Henry Wheatland.

2. *Committee to prepare Resolutions of Thanks.*

J. E. Hilgard,
Alexander Winchell,
E. S. Morse.

3. *Committee to act with the Standing Committee in Nomination of Officers for the next Meeting.*

Section A.	Section B.
E. B. Elliott,	E. B. Andrews,
S. D. Tillman,	J. H. McChesney,
F. B. Hough,	C. A. White,
C. G. Rockwood,	A. H. Tuttle.

4. *Committee to memorialize the Legislature of New York for a new Survey of Niagara Falls.*

F. A. P. Barnard,	James Hall,
Charles P. Daly,	William E. Logan,

G. W. Holley.

5. *Committee to memorialize the Legislature of Missouri in favor of publishing the results of the Geological Survey of the State.*

James Hall,	J. P. Lesley,
Louis Agassiz,	William E. Logan,
E. T. Cox,	J. S. Newberry,
J. D. Dana,	Richard Owen,
E. W. Hilgard,	J. L. Smith,
Charles H. Hitchcock,	C. A. White,
T. S. Hunt,	J. D. Whitney,
W. C. Kerr,	Alexander Winchell.

6. *Committee to report on the best methods of Organizing and Conducting State Geological Surveys.*

G. C. Swallow,	Alexander Winchell,
James Hall,	T. S. Hunt,

J. S. Newberry.

7. *Committee to arrange for the next Meeting.*

From the Standing Committee.

ASA GRAY, | JOSEPH LOVERING.

From the Association at Large.

J. L. SMITH, | O. C. MARSH,

J. D. WHITNEY.

8. *Committee to consider whether any changes are desirable in the Rules of the Constitution which relate to Membership.*

G. F. BARKER, | F. W. PUTNAM,

G. C. SWALLOW.

OFFICERS OF THE ASSOCIATION

AT

THE DUBUQUE MEETING.

J. LAWRENCE SMITH, *President.*
ALEXANDER WINCHELL, *Vice-President.*
JOSEPH LOVERING, *Permanent Secretary.*
E. S. MORSE, *General Secretary.*
WILLIAM S. VAUX, *Treasurer.*

STANDING COMMITTEE.

J. LAWRENCE SMITH,
ALEXANDER WINCHELL,
JOSEPH LOVERING,
E. S. MORSE,
ASA GRAY,
GEORGE F. BARKER,
F. W. PUTNAM,
W. S. VAUX.

LOCAL COMMITTEE.

H. T. WOODMAN, *Chairman.*
SAMUEL CALVIN, *Secretary.*

MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Meeting.	Date.	Place.	President.	Vice-President.	General Secretary.	Permanent Sec'y.	Treasurer.
1st	Sept. 20, 1848,	Philadelphia, Pa.,	W. C. Redfield,		Walter R. Johnson,		Jeffries Wyman.
2d	Aug. 14, 1849,	Cambridge, Mass.,	Joseph Henry,		E. N. Horsford,		A. L. Elwyn.
3d	Mar. 12, 1850,	Charleston, S. C.,	A. D. Bache,*		L. R. Gibbes,*		St. J. Ravenel.*
4th	Aug. 19, 1850,	New Haven, Conn.,	A. D. Bache,		E. C. Herrick,		A. L. Elwyn.
5th	May 5, 1851,	Cincinnati, Ohio,	A. D. Bache,		W. B. Rogers,	S. F. Baird,	A. L. Elwyn.
6th	Aug. 19, 1851,	Albany, N. Y.,	Louis Agassiz,		W. B. Rogers,	S. F. Baird,	A. L. Elwyn.
7th	July 28, 1853,	Cleveland, Ohio,	Benjamin Peirce,		J. D. Dana,	S. F. Baird,	A. L. Elwyn.
8th	April 26, 1854,	Washington, D. C.,	J. D. Dana,		J. Lawrence Smith,	Joseph Lovering,	J. L. LeConte.*
9th	Aug. 15, 1855,	Providence, R. I.,	John Torrey,		Wolcott Gibbs,	Joseph Lovering,	A. L. Elwyn.
10th	Aug. 20, 1856,	Albany, N. Y.,	James Hall,		B. A. Gould,	Joseph Lovering,	A. L. Elwyn.

* In the absence of the regular officer.

MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Meeting.	Date.	Place.	President.	Vice-President.	General Secretary.	Permanent Sec'y.	Treasurer.
11th	Aug. 12, 1857,	Montreal, C. E.,	J. W. Bailey,	Alexis Caswell,	John LeConte,	Joseph Lovering,	A. L. Elwyn.
12th	April 28, 1858,	Baltimore, Md.,	Alexis Caswell,*	John E. Holbrook,	W. M. Gillespie,	Joseph Lovering,	A. L. Elwyn.
13th	Aug. 3, 1859,	Springfield, Mass.,	S. Alexander,	Edward Hitchcock,	William Chauvenet,	Joseph Lovering,	A. L. Elwyn.
14th	Aug. 1, 1860,	Newport, R. I.,	Isaac Lea,	B. A. Gould,	Joseph LeConte,	Joseph Lovering,	A. L. Elwyn.
15th	Aug. 15, 1866,	Buffalo, N. Y.,	F. A. P. Barnard,	B. A. Gould,	Elias Loomis,	Joseph Lovering,	A. L. Elwyn.
16th	Aug. 21, 1867,	Burlington, Vt.,	J. S. Newberry,	Wolcott Gibbs,	C. S. Lyman,	Joseph Lovering,	A. L. Elwyn.
17th	Aug. 5, 1868,	Chicago, Ill.,	B. A. Gould,	Charles Whittlesey,	Simon Newcomb,*	Joseph Lovering,	A. L. Elwyn.
18th	Aug. 18, 1869,	Salem, Mass.,	J. W. Foster,	O. N. Rood,	O. C. Marsh,	F. W. Putnam,*	A. L. Elwyn.
19th	Aug. 17, 1870,	Troy, N. Y.,	William Chauvenet,	T. S. Hunt,†	C. F. Hartt,‡	Joseph Lovering,	A. L. Elwyn.
20th	Aug. 16, 1871,	Indianapolis, Ind.,	Asa Gray,	G. F. Barker,	F. W. Putnam,	Joseph Lovering,	W. S. Vaux.

* In the absence of the regular officer. † The President elect being absent, the Vice President took his place.

‡ Mr. F. W. Putnam was appointed to fill the place of Mr. Hartt, as he was unable to be present.

CONSTITUTION OF THE ASSOCIATION.*

OBJECTS.

THE Association shall be called THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of the United States, to give a stronger and more general impulse and a more systematic direction to scientific research in our country, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS.

RULE 1. Any person may become a member of the Association upon recommendation in writing by two members, nomination by the Standing Committee, and election by a majority of the members present.

OFFICERS.

RULE 2. The officers of the Association shall be a President, Vice-President, General Secretary, Permanent Secretary, and Treasurer. The President, Vice-President, General Secretary, and Treasurer shall be elected at each meeting for the following one; — the three first named officers not to be re-eligible for the next two meetings, and the Treasurer to be re-eligible as long as the Association may desire. The Permanent Secretary shall be elected at each second meeting, and also be re-eligible as long as the Association may desire.

* Adopted August 25, 1856, and ordered to go into effect at the opening of the Montreal Meeting. Amended at Burlington, August, 1867, and at Chicago, August, 1868.

MEETINGS.

RULE 3. The Association shall meet, at such intervals as it may determine, for one week, or longer; and the arrangements for it shall be intrusted to the officers and the Local Committee. The Standing Committee shall have power to determine the time and place of each meeting, and shall give due notice of it to the Association.

STANDING COMMITTEE.

RULE 4. There shall be a Standing Committee, to consist of the President, Vice-President, Secretaries, and Treasurer of the Association, the officers of the preceding year, the permanent Chairmen of the Sectional Committees, after these shall have been organized, and six members present from the Association at large, who shall have attended any of the previous meetings, to be elected upon open nomination by ballot on the first assembling of the Association. A majority of the whole number of votes cast, to elect. The General Secretary shall be Secretary of the Standing Committee.

The duties of the Standing Committee shall be, —

1. To assign papers to the respective sections.

2. To arrange the scientific business of the general meetings, to suggest topics, and arrange the programmes for the evening meetings.

3. To suggest to the Association the place and time of the next meeting.

4. To examine, and, if necessary, to exclude papers.

5. To suggest to the Association subjects for scientific reports and researches.

6. To appoint the Local Committee.

7. To have the general direction of publications.

8. To manage any other general business of the Association during the session, and during the interval between it and the next meeting.

9. In conjunction with four from each Section, to be elected by the Sections for the purpose, to make nominations of officers of the Association for the following meeting.

10. To nominate persons for admission to membership.

11. Before adjourning, to decide which papers, discussions, or other proceedings shall be published.

SECTIONS.

RULE 5. The Association shall be divided into two Sections, and as many sub-sections as may be necessary for the scientific business. When not otherwise ordered the sub-sections shall be as follows: SECTION A. — (1) Mathematics and Astronomy; (2) Physics and Chemistry; (3) Microscopy. SECTION B. — (1) Zoölogy and Botany; (2) Geology and Palæontology; (3) Ethnology and Archæology. The two Sections may meet as one.

SECTIONAL OFFICERS AND COMMITTEES.

RULE 6. On the first assembling of the Section, the members shall elect upon open nomination a permanent Chairman and Secretary, also three other members, to constitute, with these officers, a Sectional Committee.

The Section shall appoint, from day to day, a Chairman to preside over its meetings.

RULE 7. It shall be the duty of the Sectional Committee of each Section to arrange and direct the proceedings in their Section; to ascertain what communications are offered; to assign the order in which these communications shall appear, and the amount of time which each shall occupy.

The Sectional Committees may likewise recommend subjects for systematic investigation by members willing to undertake the researches, and to present their results at the next meeting.

The Sectional Committee may likewise recommend reports on particular topics and departments of science, to be drawn up as occasion permits, by competent persons, and presented at subsequent meetings.

REPORTS OF PROCEEDINGS.

RULE 8. Whenever practicable the proceedings shall be reported by professional reporters, or stenographers, whose reports are to be revised by the Secretaries before they appear in print.

PAPERS AND COMMUNICATIONS.

RULE 9. No paper shall be placed in the programme, unless admitted by the Sectional Committee; nor shall any be read, unless an abstract of it has been previously presented to the Secretary of the Section, who shall furnish to the Chairman the titles of papers, of which abstracts have been received.

RULE 10. The author of any paper or communication shall be at liberty to retain his right of property therein, provided he declare such to be his wish before presenting it to the Association.

RULE 11. Copies of all communications, made either to the General Association or to the Sections, must be furnished by the authors; otherwise only the titles, or abstracts, shall appear in the published proceedings.

RULE 12. All papers, either at the general or in the sectional meetings, shall be read, as far as practicable, in the order in which they are entered upon the books of the Association; except that those which may be entered by a member of the Standing Committee of the Association shall be liable to postponement by the proper Sectional Committee.

RULE 13. If any communication be not ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

RULE 14. No exchanges shall be made between members without authority of the respective Sectional Committees.

GENERAL AND EVENING MEETINGS.

RULE 15. The Standing Committee shall appoint any general meeting which the objects and interests of the Association may call for, and the evenings shall, as a rule, be reserved for general meetings of the Association.

These general meetings may, when convened for that purpose, give their attention to any topics of science which would otherwise come before the Sections.

It shall be a part of the business of these general meetings to receive the Address of the President of the last meeting; to hear such reports on scientific subjects as, from their general importance and interest, the Standing Committee shall select; also, to receive from the Chairmen of the Sections abstracts of the proceedings of their respective Sections; and to listen to communications and lectures explanatory of new and important discoveries and researches in science, and new inventions and processes in the arts.

ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

RULE 16. The Association shall be called to order by the President of the preceding meeting; and this officer having resigned the chair to the President elect, the General Secretary shall then report the number of papers relating to each department which have been registered, and the Association consider the most eligible distribution into Sections, when it shall proceed to the election of the additional members of the Standing Committee in the manner before described; the meeting shall then adjourn, and the Standing Committee, having divided the Association into Sections as directed, shall allot to each its place of meeting for the Session. The Sections shall then organize by electing their officers and their representatives in the Nominating Committee, and shall proceed to business.

PERMANENT SECRETARY.

RULE 17. It shall be the duty of the Permanent Secretary to notify members who are in arrears, to provide the necessary stationery and suitable books for the list of members and titles of papers, minutes of the general and sectional meetings, and for other purposes indicated in the rules, and to execute such other duties as may be directed by the Standing Committee or by the Association.

The Permanent Secretary shall make a report annually to the Standing Committee, at its first meeting, to be laid before the Association, of the business of which he has had charge since its last meeting.

All members are particularly desired to forward to the Permanent Secretary, so as to be received before the day appointed for the Association to convene, complete titles of all the papers which they expect to present during its meeting, with an estimate of the time required for reading each, and such abstracts of their contents as may give a general idea of their nature.

Whenever the Permanent Secretary notices any error of fact or unnecessary repetition, or any other important defect in the papers communicated for publication in the proceedings of the Association, he is authorized to commit the same to the author, or to the proper sub-committee of the Standing Committee for correction.

LOCAL COMMITTEE.

RULE 18. The Local Committee shall be appointed from among members residing at, or near, the place of meeting for the ensuing year; and it shall be the duty of the Local Committee, assisted by the officers, to make arrangements and the necessary announcements for the meeting.

The Secretary of the Local Committee shall issue a circular in regard to the time and place of meetings, and other particulars, at least one month before each meeting.

SUBSCRIPTIONS.

RULE 19. The amount of the subscription, at each meeting, of each member of the Association, shall be two dollars, and one dollar in addition shall entitle him to a copy of the proceedings of the annual meeting. These subscriptions shall be received by the Permanent Secretary, who shall pay them over, after the meeting to the Treasurer.

The admission fee of new members shall be five dollars, in addition to the annual subscription; and no person shall be considered a member of the Association until this admission fee and the subscription for the meeting at which he is elected have been paid.

RULE 20. The names of all persons two years in arrears for annual dues shall be erased from the list of members; provided that two notices of indebtedness, at an interval of at least three months, shall have been previously given.

ACCOUNTS.

RULE 21. The accounts of the Association shall be audited, annually, by auditors appointed at each meeting.

ALTERATIONS OF THE CONSTITUTION.

RULE 22. No article of this Constitution shall be altered, or amended, or set aside, without the concurrence of three-fourths of the members present, and unless notice of the proposed change shall have been given at the preceding annual meeting.

RESOLUTIONS

OF A PERMANENT AND PROSPECTIVE CHARACTER, ADOPTED AUGUST 19, 1857.

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1. No appointment may be made in behalf of the Association, and no invitation given or accepted, except by vote of the Association or its Standing Committee.

2. The General Secretary shall transmit to the Permanent Secretary for the files, within two weeks after the adjournment of every meeting, a record of the proceedings of the Association and the votes of the Standing Committee. He shall also, daily, during the meetings, provide the Chairmen of the two Sectional Committees with lists of the papers assigned to their Sections by the Standing Committee.

3. All printing for the Association shall be superintended by the Permanent Secretary, who is authorized to employ a clerk for that especial purpose.

4. The Permanent Secretary is authorized to put the proceedings of the meeting to press one month after the adjournment of the Association. Papers which have not been received at that time may be published only by title. No notice of articles not approved shall be taken in the published proceedings.

5. The Permanent Chairmen of the Sections are to be considered their organs of communication with the Standing Committee.

6. It shall be the duty of the Secretaries of the two Sections to receive copies of the papers read in their Sections, all sub-sections included, and to furnish them to the Permanent Secretary at the close of the meeting.

7. The Sectional Committees shall meet not later than 9 A.M. daily, during the meetings of the Association, to arrange the programmes of their respective Sections, including all sub-sections,

for the following day. No paper shall be placed upon these programmes which shall not have been assigned to the Section by the Standing Committee. The programmes are to be furnished to the Permanent Secretary not later than 11 A.M.

8. During the meetings of the Association, the Standing Committee shall meet daily, Sundays excepted, at 9 A.M., and the Sections be called to order at 10 A.M., unless otherwise ordered. The Standing Committee shall also meet on the evening preceding the first assembling of the Association at each annual meeting, to arrange for the business of the first day; and on this occasion three shall form a quorum.

9. Associate members may be admitted for one, two, or three years as they shall choose at the time of admission, — to be elected in the same way as permanent members, and to pay the same dues. They shall have all the social and scientific privileges of members, without taking part in the business.

10. No member may take part in the organization and business arrangement of both the Sections.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

A.

Abbe, Cleveland, Cincinnati, Ohio (16).
*Adams, C. B., Amherst, Massachusetts (1).
Adams, Edwin F., Charlestown, Massachusetts (18).
Agassiz, Alexander E. R., Cambridge, Massachusetts (18).
Agassiz, Louis, Cambridge, Massachusetts (1).
Aiken, W. E. A., Baltimore, Maryland (12).
Albert, Augustus J., Baltimore, Maryland (12).
Alexander, Stephen, Princeton, New Jersey (1).
Allen, J., Alfred Centre, New York (18)
Allen, Zachariah, Providence, Rhode Island (1).
*Alvord, Benjamin, Omaha, Nebraska (17).
*Ames, M. P., Springfield, Massachusetts (1).
Andrews, Ebenezer, Chicago, Illinois (17).
Andrews, Edmund, Chicago, Illinois (17).
Andrews, E. B., Columbus, Ohio (7).
Andrews, Joseph H., Chicago, Illinois (17).
*Appleton, Nathan, Boston, Massachusetts (1).
Atwater, Elizabeth E., Chicago, Illinois (17).
Atwater, Samuel T., Chicago, Illinois (17).
Austin, E. P., Cambridge, Massachusetts (18).

B.

Babcock, George, Troy, New York (19).
Babcock, Henry H., Chicago, Illinois (17).
*Bache, Alexander D., Washington, District of Columbia (1).
Bacon, John, Jr., Boston, Massachusetts (1).

NOTE. — Names of deceased members are marked with an asterisk [*]. The figure at the end of each name refers to the meeting at which the election took place.

*Bailey, J. W., West Point, New York (1).
Bailey, Loring W., Frederickton, New Brunswick (18).
Baird, Lyman, Chicago, Illinois (17).
Baird, S. F., Washington, District of Columbia (1).
Bannister, Henry M., Washington, District of Columbia (17).
Bardwell, F. W., Lawrence, Kansas (18).
Barker, G. F., New Haven, Connecticut (18).
Barnard, F. A. P., New York, New York (7).
Barnard, J. G., New York, New York (14).
Basnett, Thomas, Ottawa, Illinois (8).
Batchelder, J. H., Salem, Massachusetts (18).
Batchelder, J. M., Cambridge, Massachusetts (8).
Beaty, John F., Chicago, Illinois (17).
*Beck, C. F., Philadelphia, Pennsylvania (1).
*Beck, Lewis C., New Brunswick, New Jersey (1).
*Beck, T. Romeyn, Albany, New York (1).
Beebe, G. D., Chicago, Illinois (17).
*Bell, Samuel N., Manchester, New Hampshire (7).
Benjamin, E. B., New York, New York (19).
Bethune, Charles J. S., Port Hope, Canada (18).
Bickmore, Albert S., New York, New York (17).
Bicknall, Edwin, Cambridge, Massachusetts (18).
Bill, Charles, Springfield, Massachusetts (17).
*Binney, Amos, Boston, Massachusetts (1).
*Binney, John, Boston, Massachusetts (3).
Blake, Eli W., Providence, Rhode Island (15).
Blake, Eli W., New Haven, Connecticut (1).
Blake, W. P., San Francisco, California (2).
*Blanding, William, Rhode Island (1).
Blaney, J. Van Zandt, Chicago, Illinois (12).
Blatchford, Eliphalet W., Chicago, Illinois (17).
Blatchley, S. L., New Haven, Connecticut (19).
Bolles, E. C., Salem, Massachusetts (17).
Bolton, H. C., New York, New York (17).
*Bomford, George, Washington, District of Columbia (1).
Bontencou, R. B., Troy, New York (19).
Bouvé, Thomas T., Boston, Massachusetts (1).
Bowditch, Henry I., Boston, Massachusetts (2).
Bowen, Chauncey W., Chicago, Illinois (17).
Bowen, James H., Chicago, Illinois (17).
Boynton, Susan P., Lynn, Massachusetts (19).
Brackett, C. F., Brunswick, Maine (19).
Bradley, Francis, Chicago, Illinois (17).
Bradley, L., Jersey City, New Jersey (15).
Brevoort, J. Carson, Brooklyn, New York (1).
Briggs, A. D., Springfield, Massachusetts (13).
Briggs, D. H., Norton, Massachusetts (18).
Briggs, S. A., Chicago, Illinois (17).
Brigham, Charles H., Chicago, Illinois (17).

Bross, William, Chicago, Illinois (7).
Brown, Robert, Jr., Cincinnati, Ohio (11).
Brush, George J., New Haven, Connecticut (11).
Bryan, Oliver N., Marshall Hall P. O., Maryland (18).
Bryan, Thomas B., Chicago, Illinois (17).
Buchanan, Robert, Cincinnati, Ohio (2).
Burbank, L. S., Lowell, Massachusetts (18).
Burden, Henry, Jr., Troy, New York (19).
*Burnap, G. W., Baltimore, Maryland (12).
*Burnett, Waldo I., Boston, Massachusetts (1).
Burroughs, J. C., Chicago, Illinois (17).
Bush, Stephen, Waterford, New York (19).
Bushee, James, Worcester, Massachusetts (9).
Butler, Thomas B., Norwalk, Connecticut (10).

C.

Calhoun, John B., Chicago, Illinois (17).
Canby, William M., Wilmington, Delaware (17).
*Carpenter, Thornton, Camden, South Carolina (7).
*Carpenter, William M., New Orleans, Louisiana (1).
Carter, Asher, Chicago, Illinois (17).
Case, Leonard, Cleveland, Ohio (15).
Case, L. B., Richmond, Indiana (17).
*Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, Rhode Island (2).
Cattell, William C., Easton, Pennsylvania (15).
Chadbourn, P. A., Williamstown, Massachusetts (10).
Chandler, William H., New York, New York (19).
Chanute, O., Lawrence, Kansas (17).
Chapman, F. M., Chicago, Illinois (17).
*Chapman, N., Philadelphia, Pennsylvania (1).
Chase, George I., Providence, Rhode Island (1).
Chase, R. Stuart, Haverhill, Massachusetts (18).
*Chase, S., Dartmouth, New Hampshire (2).
*Chauvenet, William, St. Louis, Missouri (1).
Chesbrough, E. S., Chicago, Illinois (2).
*Clapp, Asahel, New Albany, Indiana (1).
Clark, John E., Yellow Springs, Ohio (17).
*Clark, Joseph, Cincinnati, Ohio (5).
Clarke, F. W., Boston, Massachusetts (18).
*Cleveland, A. B., Cambridge, Massachusetts (2).
Cochran, D. H., Brooklyn, New York (15).
Coffin, James H., Easton, Pennsylvania (1).
Coffin, John H. C., Washington, District of Columbia (1).
Colbert, E., Chicago, Illinois (17).
*Cole, Thomas, Salem, Massachusetts (1).
*Coleman, Henry, Boston, Massachusetts (1).
Collett, John, Eugene, Indiana (17).

Conkling, Frederick A., New York, New York (11).
Cook, George H., New Brunswick, New Jersey (18).
Cooke, C., Salem, Massachusetts (18).
Cope, Edward D., Philadelphia, Pennsylvania (17).
Copes, Joseph S., New Orleans, Louisiana (11).
*Corning, Erastus, Albany, New York (6).
Cox, Edward T., Indianapolis, Indiana (19).
Cramp, J. M., Wolfville, Nova Scotia (11).
Crosby, Alpheus, Salem, Massachusetts (10).
Crosby, Thomas R., Hanover, New Hampshire (18).
Culver, Howard Z., Chicago, Illinois (17).
Cummings, John, Woburn, Massachusetts (18).
Cummings, Joseph, Middletown, Connecticut (13).
Curtis, Josiah, Boston, Massachusetts (18).
Cutting, Hiram A., Lunenburg, Vermont (17).

D.

Dall, William H., Washington, District of Columbia (18).
Dalrymple, E. A., Baltimore, Maryland (11).
Dana, James D., New Haven, Connecticut (1).
Danforth, Edward, Albany, New York (11).
Davis, James, Boston, Massachusetts (1).
Davis, N. S., Chicago, Illinois (17).
Dawson, J. W., Montreal, Canada (10).
*Dean, Amos, Albany, New York (6).
Dean, George W., Fall River, Massachusetts (15).
*Dearborn, George H. A. S., Roxbury, Massachusetts (1).
*Dekay, James E., New York, New York (1).
Delano, B. L., Boston, Massachusetts (16).
Delano, Joseph C., New Bedford, Massachusetts (5).
De Laski, John, Vinalhaven, Maine (18).
Devereux, J. H., Cleveland, Ohio (18).
*Dewey, Chester, Rochester, New York (1).
Dexter, G. M., Boston, Massachusetts (11).
Dinwiddie, Robert, New York, New York (1).
Dixwell, Epes S., Cambridge, Massachusetts (1).
Doggett, Kate N., Chicago, Illinois (17).
Doggett, William E., Chicago, Illinois (17).
Dorr, E. P., Buffalo, New York (15).
Doughty, John W., Newburgh, New York (19).
Drowne, Charles, Troy, New York (6).
*Ducatel, J. T., Baltimore, Maryland (1).
*Dumont, A. H., Newport, Rhode Island (14).
*Duncan, Lucius C., New Orleans, Louisiana (10).
Duncan, T. C., Chicago, Illinois (17).
*Dunn, R. P., Providence, Rhode Island (14).
Dyer, Elisha, Providence, Rhode Island (9).

E.

Easton, Norman, Fall River, Massachusetts (14).
Eaton, Daniel C., New Haven, Connecticut (13).
Eaton, D. G., Brooklyn, New York (19).
Eaton, James H., Beloit, Wisconsin (17).
Edwards, A. M., New York, New York (18).
Edwards, J. B., Montreal, Canada (17).
Eimbeck, William, St. Louis, Missouri (17).
Eliot, Charles W., Cambridge, Massachusetts (14).
Elliott, Ezekiel B., Washington, District of Columbia (10).
Elwyn, Alfred L., Philadelphia, Pennsylvania (1).
Emerson, Benjamin K., Amherst, Massachusetts (19).
Emerson, George B., Boston, Massachusetts (1).
Emerton, James H., Salem, Massachusetts (18).
Englemann, George, St. Louis, Missouri (1).
Engstrom, A. B., Burlington, New Jersey (1).
Ennis, Jacob, Philadelphia, Pennsylvania (19).
Eustis, Henry L., Cambridge, Massachusetts (2).
Evans, Asher B., Lockport, New York (19).
*Everett, Edward, Boston, Massachusetts (2).
Ewing, Thomas, Lancaster, Ohio (5).

F.

Fairbanks, Henry, St. Johnsbury, Vermont (14).
Farmer, Moses G., Salem, Massachusetts (9).
Farnham, Thomas, Buffalo, New York (15).
Farrar, Henry W., Chicago, Illinois (17).
Fellowes, R. S., New Haven, Connecticut (18).
Fenton, William, Troy, New York (18).
Ferrell, William, Cambridge, Massachusetts (11).
Ferris, Isaac, New York, New York (6).
Feuchtwanger, Louis, New York, New York (11).
Fisher, Clark, Trenton, New Jersey (19).
Fisher, Davenport, Annapolis, Maryland (17).
Fisher, Mark, Trenton, New Jersey (10).
*Fitch, Alexander, Hartford, Connecticut (1).
Fitch, Edward H., Ashtabula, Ohio (11).
Fitch, O. H., Ashtabula, Ohio (7).
*Forbush, E. B., Buffalo, New York (15).
Ford, S. W., Troy, New York (19).
Forsyth, Robert, Troy, New York (19).
Foster, Henry, Clifton, New York (17).
Foster, John, Schenectady, New York (17).
Foster, J. W., Chicago, Illinois (1).
*Fox, Charles, Grosse Isle, Michigan (7).
Frothingham, [redacted] York (11).

G.

Gavit, John E., New York, New York (1).
*Gay, Martin, Boston, Massachusetts (1).
*Gibbon, J. H., Charlotte, North Carolina (8).
Gill, Theodore, Washington, District of Columbia (17).
*Gillespie, W. M., Schenectady, New York (10).
Gilman, Daniel C., New Haven, Connecticut (10).
*Gilmor, Robert, Baltimore, Maryland (1).
Glazier, Sarah M., Chelsea, Massachusetts (19).
Goessman, C. A., Amherst, Massachusetts (18).
Gold, Theodore S., West Cornwall, Connecticut (4).
*Gould, Augustus A., Boston, Massachusetts (11).
*Gould, B. A., Boston, Massachusetts (2).
Gould, B. A., Cambridge, Massachusetts (2).
*Graham, James D., Washington, District of Columbia (1).
Gray, Asa, Cambridge, Massachusetts (1).
*Gray, James H., Springfield, Massachusetts (6).
Greeley, Samuel S., Chicago, Illinois (17).
Green, Traill, Easton, Pennsylvania (1).
*Greene, Benjamin D., Boston, Massachusetts (1).
Greene, Dascom, Troy, New York (17).
Greene, Francis C., Easthampton, Massachusetts (11).
Gregory, J. J. H., Marblehead, Massachusetts (18).
*Griffith, Robert E., Philadelphia, Pennsylvania (1).
Grimes, J. S., New York, New York (17).
Grinnan, A. G., Orange Court House, Virginia (7).
Grover, Z., Chicago, Illinois (17).
Guyot, Arnold, Princeton, New Jersey (1).

H.

*Hackley, Charles W., New York, New York (4).
Hadley, George, Buffalo, New York (6).
Hagen, Hermann A., Cambridge, Massachusetts (17).
Haldeman, S. S., Columbia, Pennsylvania (1).
Hale, Edwin M., Chicago, Illinois (17).
*Hale, Enoch, Boston, Massachusetts (1).
Hale, William H., Albany, New York (19).
Hall, Benjamin H., Troy, New York (19).
Hall, George E., Cleveland, Ohio (19).
Hall, James, Albany, New York (1).
Hall, L. B., Windsor, Vermont (18).
Hall, N. K., Buffalo, New York (7).
Hambly, J. B., Portsmouth, Rhode Island (18).
Hamel, Thomas, Quebec, Canada (18).
Hamlin, A. C., Bangor, Maine (10).
Hanaman, C. E., Troy, New York (19).
Hance, Ebenezer, Morrisville, Pennsylvania (7).

Hanover, M. D., Cincinnati, Ohio (13).
*Hare, Robert, Philadelphia, Pennsylvania (11).
*Harlan, Joseph G., Haverford, Pennsylvania (8).
*Harlan, Richard, Philadelphia, Pennsylvania (1).
Harris, A. A., Cambridge, Massachusetts (17).
Harris, James W., Cambridge, Massachusetts (17).
*Harris, Thaddeus W., Cambridge, Massachusetts (1).
Harrison, B. F., Wallingford, Connecticut (11).
*Hart, Simeon, Farmington, Connecticut (1).
Hart, William H., Troy, New York (19).
Hartshorne, Henry, Philadelphia, Pennsylvania (12).
Haven, Joseph, Chicago, Illinois (17).
Hawkins, B. W., New York, New York (17).
*Hayden, H. H., Baltimore, Maryland (1).
Hayes, George E., Buffalo, New York (15).
*Hayward, James, Boston, Massachusetts (1).
Hedrick, B. S., Washington, District of Columbia (19).
Henry, Joseph, Washington, District of Columbia (1).
Herzer, W., Columbus, Ohio (15).
Hickcox, S. V. R., Chicago, Illinois (17).
Hilgard, Eugene W., Oxford, Mississippi (11).
Hilgard, Julius E., Washington, District of Columbia (4).
Hilgard, Theodore C., St. Louis, Missouri (17).
Hill, S. W., Hancock, Lake Superior (6).
Hill, Thomas, Waltham, Massachusetts (8).
Hinrichs, Gustavus, Iowa City, Iowa (17).
Hitchcock, Charles H., Hanover, New Hampshire (11).
*Hitchcock, Edward, Amherst, Massachusetts (1).
Hitchcock, Edward, Amherst, Massachusetts (4).
Hitt, Isaac R., Chicago, Illinois (17).
Hoadley, E. S., Springfield, Massachusetts (13).
*Holbrook, J. E., Charleston, South Carolina (1).
Holley, George W., Troy, New York (19).
Holmes, E. L., Chicago, Illinois (17).
Homes, Henry A., Albany, New York (11).
Hopkins, Albert, Williamstown, Massachusetts (19).
Horribin, William T., Bennington, Vermont (19).
Horsford, E. N., Cambridge, Massachusetts (1).
*Horton, William, Craigville, New York (1).
Hough, Franklin B., Lowville, New York (4).
Hough, G. W., Albany, New York (15).
*Houghton, Douglas, Detroit, Michigan (1).
House, John C., Waterford, New York (19).
Howell, Robert, Nichols, New York (6).
Hoy, Philo R., Racine, Wisconsin (17).
Hubbard, Gurdon S., Chicago, Illinois (17).
Hubbard, Oliver P., New Haven, Connecticut (1).
Hubbard, Sara A., Chicago, Illinois (17).
*Hubbert, James, Richmond, Province of Quebec (16).

Humphrey, D., Lawrence, Massachusetts (18).
Hunt, Charles S., New York, New York (17).
*Hunt, E. B., Washington, District of Columbia (2).
*Hunt, Freeman, New York, New York (11).
Hunt, George, Providence, Rhode Island (9).
Hunt, T. Sterry, Montreal, Canada (1).
Huntington, J. H., Hanover, New Hampshire (19).
Hyatt, Alpheus, Salem, Massachusetts (18).
Hyatt, James, Bangall, New York (10).

I.

*Ives, Thomas P., Providence, Rhode Island (10).

J.

Jenks, J. W. P., Middleboro', Massachusetts (2).
Jillson, B. C., Pittsburgh, Pennsylvania (14).
*Johnson, W. R., Washington, District of Columbia (1).
Johnston, John, Middletown, Connecticut (1).
*Jones, Catesby A. R., Washington, District of Columbia (8).
Joy, C. A., New York, New York (8).
Judd, Orange, New York, New York (4).

K.

Kedzie, J. H., Chicago, Illinois (17).
Kellogg, Giles B., Troy, New York (19).
Kellogg, Justin, Troy, New York (19).
Keely, G. W., Waterville, Maine (1).
Keep, N. C., Boston, Massachusetts (18).
Kerr, W. C., Raleigh, North Carolina (10).
Kimball, J. P., New York, New York (15).
King, Mary B. A., Rochester, New York (15).
Kirkpatrick, James A., Philadelphia, Pennsylvania (7).
Kirkwood, Daniel, Bloomington, Indiana (7).
Kite, Thomas, Cincinnati, Ohio (5).
Klippart, John H., Columbus, Ohio (17).
Knickerbocker, Charles, Chicago, Illinois (17).

L.

Lambert, Thomas R., Charlestown, Massachusetts (18).
Langley, S. P., Allegheny, Pennsylvania (18).
Lapham, Increase A., Milwaukee, Wisconsin (8).
*Lasel, Edward, Williamstown, Massachusetts (1).
Lattimore, S. A., Rochester, New York (15).
Lawrence, Edward, Charlestown, Massachusetts (18).
Lawrence, George N., New York, New York (7).
Lea, Isaac, Philadelphia, Pennsylvania (1).
Leakin, George A., Baltimore, Maryland (17).

Leckie, Robert G., Actonvale, Quebec (19).
*Lederer Baron von, Washington, District of Columbia (1).
Lennon, W. H., Brockport, New York (19).
Lesley, Joseph, Jr., Philadelphia, Pennsylvania (8).
Lesley, J. P., Philadelphia, Pennsylvania (2).
*Lieber, Oscar M., Columbia, South Carolina (8).
*Lincklaen, Ledyard, Cazenovia, New York (1).
Lincoln, Robert T., Chicago, Illinois (17).
Lindsley, J. B., Nashville, Tennessee (1).
*Linsley, James H., Stafford, Connecticut (1).
Little, George, Oxford, Mississippi (15).
Locke, Luther F., Nashua, New Hampshire (7).
Lockwood, Samuel, Freehold, New Jersey (18).
Logan, William E., Montreal, Canada (1).
Lombard, Benjamin, Chicago, Illinois (17).
Loomis, Elias, New Haven, Connecticut (1).
*Loosey, Charles F., New York, New York (12).
*Lothrop, Joshua R., Buffalo, New York (15).
Lovering, Joseph, Cambridge, Massachusetts (2).
Lupton, N. T., Tuscaloosa, Alabama (17).
Lyman, B. S., Philadelphia, Pennsylvania (15).
Lyman, Chester S., New Haven, Connecticut (14).
Lyman, Henry M., Chicago, Illinois (17).
Lyon, Henry, Charlestown, Massachusetts (18).

M.

Maack, G. A., Cambridge, Massachusetts (18).
MacArthur, Charles L., Troy, New York (19).
Mack, David, Belmont, Massachusetts (18).
McCagg, Ezra B., Chicago, Illinois (17).
McClellan, R. H., Troy, New York (19).
*M'Conihe, Isaac, Troy, New York (4).
McCoy, Amasa, Chicago, Illinois (17).
McMurtrie, Horace, Boston, Massachusetts (17).
McNeil, J. A., Grand Rapids, Michigan (18).
McRae, John, Camden, South Carolina (3).
Marcy, Oliver, Evanston, Illinois (10).
*Marsh, Dexter, Greenfield, Massachusetts (1).
Marsh, H. H., Chicago, Illinois (17).
Marsh, O. C., New Haven, Connecticut (15).
Marshall, Orasmus H., Buffalo, New York (15).
*Mather, William W., Columbus, Ohio (1).
Mauran, J., New York, New York (2).
Mayer, Alfred M., Hoboken, New Jersey (19).
Mayhew, D. P., Ypsilanti, Michigan (13).
Maynard, Alleyne, Cleveland, Ohio (7).
Maynard, George W., Troy, New York (10).
Meade, George G., Philadelphia, Pennsylvania (15).

Means, A., Oxford, Georgia (5).
Meehan, Thomas, Germantown, Pennsylvania (17).
Meek, F. B., Washington, District of Columbia (6).
Meigs, James A., Philadelphia, Pennsylvania (12).
Miles, Henry H., Quebec, Canada East (11).
Minifie, William, Baltimore, Maryland (12).
Mitchell, Maria, Poughkeepsie, New York (4).
Mitchell, William H., Florence, Alabama (17).
Monroe, William, Boston, Massachusetts (18).
Morgan, Lewis H., Rochester, New York (10).
Morison, N. H., Baltimore, Maryland (17).
Morley, Edward W., Hudson, Ohio (18).
Morris, John G., Baltimore, Maryland (12).
Morris, Oran W., New York, New York (19).
Morse, Edward S., Salem, Massachusetts (18).
Morton, Henry, Hoboken, New Jersey (18).
*Morton, S. G., Philadelphia, Pennsylvania (1).
Murray, David, New Brunswick, New Jersey (11).
Myers, W. H., Fort Wayne, Indiana (17).

N.

Nason, Henry B., Troy, New York (13).
Nelson, Cleland K., Annapolis, Maryland (12).
Newberry, J. S., New York, New York (5).
Newcomb, Simon, Washington, District of Columbia (13).
*Newton, E. H., Cambridge, New York (1).
Newton, Hubert A., New Haven, Connecticut (6).
Newton, John, Pensacola, Florida (7).
Nichols, Charles A., Providence, Rhode Island (17).
Nichols, William R., Boston, Massachusetts (18).
Nickel, George D., Connellsville, Pennsylvania (19).
*Nicollett, J. N., Washington, District of Columbia (1).
Niles, W. H., Cambridge, Massachusetts (16).
*Norton, J. P., New Haven, Connecticut (1).
Norton, W. A., New Haven, Connecticut (6).

O.

*Oakes, William, Ipswich, Massachusetts (1).
Ogden, Mahlon D., Chicago, Illinois (17).
Ogden, W. B., Chicago, Illinois (17).
Oliver, James Edward, Lynn, Massachusetts (7).
*Olmsted, Alexander F., New Haven, Connecticut (4).
*Olmsted, Denison, New Haven, Connecticut (1).
*Olmsted, Denison, Jr., New Haven, Connecticut (1).
Ordway, John M., Boston, Massachusetts (9).
Orton, Edward, Yellow Springs, Ohio (19).
Orton, James, Poughkeepsie, New York (18).

Osborne, A. O., Waterville, New York (19).
Osborne, Ada M., Waterville, New York (19).
Osten, Sacken, Baron R. von, New York, New York (10).

P.

Packard, A. S., Jr., Salem, Massachusetts (16).
Page, Peter, Chicago, Illinois (17).
Paine, Cyrus F., Rochester, New York (12).
Paine, Nathaniel, Worcester, Massachusetts (18).
Painter, Minshall, Lima, Pennsylvania (7).
*Parkman, Samuel, Boston, Massachusetts (1).
Parmelee, Dubois D., New York, New York (15).
Parry, Charles C., Washington, District of Columbia (6).
Patton, William W., Chicago, Illinois (18).
Peabody, S. H., Chicago, Illinois (17).
Peck, W. A., Troy, New York (19).
Peckham, S. F., Providence, Rhode Island (18).
Peirce, Benjamin, Cambridge, Massachusetts (1).
Peirce, B. O., Beverly, Massachusetts (18).
Perkins, George H., Burlington, Vermont (17).
Perkins, George R., Utica, New York (7).
Perkins, Henry C., Newburyport, Massachusetts (18).
Perkins, Maurice, Schenectady, New York (15).
Perry, John B., Cambridge, Massachusetts (16).
*Perry, M. C., New York, New York (10).
Phelps, Almira L., Baltimore, Maryland (13).
Phelps, Charles E., Baltimore, Maryland (18).
Phippen, George D., Salem, Massachusetts (18).
Pickering, Edward C., Boston, Massachusetts (18).
*Plumb, Ovid, Salisbury, Connecticut (9).
Pope, Charles A., St. Louis, Missouri (12).
*Porter, John A., New Haven, Connecticut (14).
Pourtales, L. F., Washington, District of Columbia (1).
Powell, Edwin, Chicago, Illinois (17).
Pratt, William H., Davenport, Iowa (17).
Prentiss, A. N., Ithaca, New York (17).
Prescott, William, Concord, New Hampshire (1).
Pruyn, J. V. L., Albany, New York (1).
*Pugh, Evan, Centre Co., Pennsylvania (14).
Pumpelly, Raphael, Cambridge, Massachusetts (17).
Putnam, Adelaide M., Salem, Massachusetts (19).
Putnam, F. W., Salem, Massachusetts (10).

Q.

Quincy, Edmund, Jr., Boston, Massachusetts (11).

R.

Rauch, J. H., Chicago, Illinois (11).
Raymond, R. W., New York, New York (15).

Read, Daniel, Columbia, Missouri (17).
Redfield, John H., Philadelphia, Pennsylvania (1).
*Redfield, William C., New York, New York (1).
Reybold, Mary, Delaware City, Delaware (19).
Rice, William N., Middletown, Connecticut (18).
Riley, Charles V., St. Louis, Missouri (17).
Ritchie, E. S., Boston, Massachusetts (10).
Robertson, Thomas D., Rockford, Illinois (10).
Rochester, Thomas F., Buffalo, New York (15).
Rockwell, Alfred P., New Haven, Connecticut (10).
Rockwell, John, La Salle, Illinois (11).
*Rockwell, John A., Norwich, Connecticut (10).
Rockwell, Joseph P., Boston, Massachusetts (17).
Rogers, Fairman, Philadelphia, Pennsylvania (11).
*Rogers, James B., Philadelphia, Pennsylvania (1).
Rogers, Robert E., Philadelphia, Pennsylvania (18).
Rogers, W. A., Alfred Centre, New York (15).
Rogers, W. B., Boston, Massachusetts (1).
Rood, O. N., New York, New York (14).
Roosevelt, Clinton, New York, New York (11).
Root, Edward W., Clinton, New York (17).
Rumsey, Bronson C., Buffalo, New York (15).
Rumsey, George T., Chicago, Illinois (17).
Runkle, J. D., Boston, Massachusetts (2).
Rutherford, Louis M., New York, New York (13).
Ryerson, Joseph T., Chicago, Illinois (17).

S.

Safford, J. M., Nashville, Tennessee (6).
Safford, Truman H., Chicago, Illinois (13).
Samson, George W., New York, New York (18).
Sanborn, Francis G., Boston, Massachusetts (18).
Sanders, Benjamin D., Wellsburg, West Virginia (19).
Scammon, J. Young, Chicago, Illinois (17).
Schanck, J. Stillwell, Princeton, New Jersey (4).
Schott, Charles A., Washington, District of Columbia (8).
Scudder, Samuel H., Cambridge, Massachusetts (13).
Seely, Charles A., New York, New York (18).
Seward, William H., Auburn, New York (1).
Seymour, W. P., Troy, New York (19).
Sheafer, P. W., Pottsville, Pennsylvania (4).
Sheldon, Edwin H., Chicago, Illinois (17).
Sherwood, Andrew, Mansfield, Pennsylvania (18).
Sias, Solomon, Charlotteville, New York (10).
Sill, Elisha N., Cuyahoga Falls, Ohio (6).
*Silliman, Benjamin, New Haven, Connecticut (1).
Silliman, Benjamin, New Haven, Connecticut (1).
Silliman, Justus M., Easton, Pennsylvania (19).
Smith, A. D., Providence, Rhode Island (14).

Smith, J. L., Louisville, Missouri (14).
*Smith, J. V., Cincinnati, Ohio (5).
Smith, James Y., Providence, Rhode Island (9).
*Smith, Lyndon A., Newark, New Jersey (9).
Smith, Rollin A., Fond-du-Lac, Wisconsin (18).
Snell, Eben S., Amherst, Massachusetts (2).
*Sparks, Jared, Cambridge, Massachusetts (2).
Spencer, Charles A., Brooklyn, New York (14).
Sprague Albert A., Chicago, Illinois (17).
Spring, Charles H., Boston, Massachusetts (13).
Squier, E. G., New York, New York (18).
Stanard, Benjamin A., Cleveland, Ohio (6).
Stearns, Josiah A., Boston, Massachusetts (10).
Stearns, R. E. C., San Francisco, California (18).
Steiner, Lewis H., Frederick City, Maryland (7).
Stephens, W. H., Lowville, New York (18).
Stimpson, Frederick E., Boston, Massachusetts (18).
Stimpson, Thomas M., Peabody, Massachusetts (18).
Stimpson, William, Chicago, Illinois (12).
Storke, Helen L., Auburn, New York (19).
Stockwell, John N., Cleveland, Ohio (18).
Stoddard, O. N., Oxford, Ohio (7).
Stone, Samuel, Chicago, Illinois (17).
Storer, D. H., Boston, Massachusetts (1).
Storer, Frank H., Boston, Massachusetts (13).
Stoughton, T. M., Factory Village, Massachusetts (18).
Sullivant, W. S., Columbus, Ohio (7).
Swallow, G. C., Columbia, Missouri (10).
Swasey, Oscar F., Beverly, Massachusetts (17).

T.

*Tallmadge, James, New York, New York (1).
*Taylor, Richard C., Philadelphia, Pennsylvania (1).
Tenney, Sanborn, Williamstown, Massachusetts (17).
*Teschemacher, J. E., Boston, Massachusetts (1).
Thompson, Aaron R., New York, New York (1).
Thompson, Harvey M., Chicago, Illinois (17).
Thompson, Robert H., Troy, New York (19).
*Thompson, Z., Burlington, Vermont (1).
*Thurber, Isaac, Providence, Rhode Island (9).
Tillman, S. D., Jersey City, New Jersey (15).
Tingley, Jeremiah, Meadville, Pennsylvania (15).
Tingley, Joseph, Greencastle, Indiana (14).
Tolles, Robert B., Boston, Massachusetts (15).
Torrey, John, New York, New York (1).
*Totten, J. G., Washington, District of Columbia (1).
Townsend, Franklin, Albany, New York (4).
*Townsend, John K., Philadelphia, Pennsylvania (1).
Townshend, N. S., Avon, Ohio (17).

Tracy, John F., Chicago, Illinois (17).
Trembly, J. B., Toledo, Ohio (17).
*Troost, Gerard, Nashville, Tennessee (1).
Trowbridge, W. P., New Haven, Connecticut (10).
True, Nathaniel T., Bethel, Maine (17).
*Tuomey, M., Tuscaloosa, Alabama (1).
Turner, R. S., Reading, Pennsylvania (18).
Tuttle, Albert H., Cleveland, Ohio (17).
Twining, A. C., New Haven, Connecticut (18).
*Tyler, Edward R., New Haven, Connecticut (1).
Tyson, Philip T., Baltimore, Maryland (12).

U.

Uhler, Philip R., Baltimore, Maryland (19).
Upham, J. Baxter, Boston, Massachusetts (14).
Upton, George P., Chicago, Illinois (17).

V.

Vail, Hugh D., Philadelphia, Pennsylvania (18).
*Vancleve, John W., Dayton, Ohio (1).
Van der Weyde, P. H., New York, New York (17).
Van Horne, W. C., Chicago, Illinois (19).
*Vanuxem, Lardner, Bristol, Pennsylvania (1).
Vaux, William S., Philadelphia, Pennsylvania (1).
Verrill, A. E., New Haven, Connecticut (16).
Vose, George L., Minneapolis, Minnesota (15).

W.

Waddell, John N., Oxford, Mississippi (17).
*Wadsworth, James S., Genesee, New York (2).
*Wagner, Tobias, Philadelphia, Pennsylvania (9).
Walker, George C., Chicago, Illinois (17).
Walker, J. R., New Orleans, Louisiana (19).
*Walker, Joseph, Oxford, New York (10).
*Walker, Sears C., Washington, District of Columbia (1).
*Walker, Timothy, Cincinnati, Ohio (4).
Walling, H. F., Easton, Pennsylvania (16).
Wanzer, Ira, Lanesville, Connecticut (18).
Ward, Henry A., Rochester, New York (13).
Ward, R. H., Troy, New York (17).
Warder, Robert B., Champaign, Illinois (19).
Warner, James D., Brooklyn, New York (18).
Warren, G. K., Washington, District of Columbia (12).
Warren, G. W., Boston, Massachusetts (18).
*Warren, John C., Boston, Massachusetts (1).
Warren, S. Edward, Troy, New York (17).
Watson, James C., Ann Arbor, Michigan (13).
Watson, William, Boston, Massachusetts (12).
Webb, Benjamin, Jr., Salem, Massachusetts (18).

*Webster, H. B., Albany, New York (1).
*Webster, J. W., Cambridge, Massachusetts (1).
*Webster, M. H., Albany, New York (1).
Webster, Nathan B., Norfolk, Virginia (7).
Wells, Daniel H., New Haven, Connecticut (18).
Wells, George A., Troy, New York (19).
Wendell, August, Troy, New York (19).
Wenz, J., New Orleans, Louisiana (15).
West, Charles E., Brooklyn, New York (1).
Wheatland, Henry, Salem, Massachusetts (1).
*Wheatland, Richard H., Salem, Massachusetts (13)
Wheatley, Charles M., Phœnixville, Pennsylvania (1).
Wheeler, T. B., Montreal, Canada (11).
Wheildon, W. W., Charlestown, Massachusetts (13).
White, C. A., Iowa City, Iowa (17).
Whitfield, R. P., Albany, New York (18).
Whitney, Asa, Philadelphia, Pennsylvania (1).
Whitney, J. D., Cambridge, Massachusetts (1).
Whitney, Mary W., Waltham, Massachusetts (19).
Whitney, William D., New Haven, Connecticut (12).
Whittlesey, Charles, Cleveland, Ohio (1).
Wilber, G. M., Pine Plains, New York (19).
*Willard, Emma, Troy, New York (15).
Williams, Henry W., Boston, Massachusetts (11).
Williams, H. S., New Haven, Connecticut (18).
Williamson, R. S., San Francisco, California (12).
Wilson, Charles L., Chicago, Illinois (17).
Winchell, Alexander, Ann Arbor, Michigan (3).
Winchell, N. H., Ann Arbor, Michigan (19).
Winslow, Ferdinand S., Chicago, Illinois (17).
*Woodbury, L., Portsmouth, New Hampshire (1).
Woodworth, John M., Chicago, Illinois (17).
Worthen, A. H., Springfield, Illinois (5).
Wright, A. W., Williamstown, Massachusetts (14).
Wright, Chauncey, Cambridge, Massachusetts (9).
*Wright, John, Troy, New York (1).
Wurtele, Louis C., Acton Vale, Canada East (11).
Wurtz, Henry, New York, New York (10).
Wyman, Jeffries, Cambridge, Massachusetts (1).

Y.

Youmans, E. L., New York, New York (6).
Young, Charles A., Hanover, New Hampshire (18).
*Young, Ira, Hanover, New Hampshire (7).
Young, William H., Troy, New York (19).

This list contains six hundred and fifty names, of which one hundred and twenty-two are of deceased members. The names of those who were chosen at Indianapolis, and who have already [illegible] incorporated into the general catalogue of members, but

MEMBERS

WHO JOINED AT

THE INDIANAPOLIS MEETING.

Ainsworth, Frank B., Plainfield, Indiana.
Alexander, John S., Philadelphia, Pennsylvania.
Austin, Thomas R., Terre Haute, Indiana.
Avery, Alida C., Poughkeepsie, New York.
Aydelotte, William, Sullivan, Indiana.

Barnard, Jehiel, Indianapolis, Indiana.
Bassett, George W., Vandalia, Illinois.
Bell, Eliza C., Indianapolis, Indiana.
Bell, James D., New York, New York.
Berry, Daniel M., Indianapolis, Indiana.
Billingsley, J. J. W., Spring Valley, Indiana.
Boadle, John, Haddonfield, New Jersey.
Bowen, Silas T., Indianapolis, Indiana.
Bowman, Thomas, Greencastle, Indiana.
Braden, William, Indianapolis, Indiana.
Breneman, A. A., Agricultural College, Pennsylvania.
Brewer, W. H., New Haven, Connecticut.
Buckhout, W. A., Agricultural College, Pennsylvania.
Bullard, William M., Indianapolis, Indiana.
Burford, William B., Indianapolis, Indiana.
Burgess, Abby L., Oxford, Ohio.

Carrier, Joseph C., Notre Dame, Indiana.
Carrington, Henry B., Crawfordsville, Indiana.
Carson, James P., New York, New York.
Coffinberry, W. L., Grand Rapids, Michigan.
Colgan, Charles J., Indianapolis, Indiana.
Coulson, Mary, Mason, Ohio.

Dana, Charles P., New York, New York.
Davis, F. A. W., Indianapolis, Indiana.
Day, F. H., Wauwatosa, Wisconsin.
Day, Henry, Indianapolis, Indiana.
Day, Henry, Indianapolis, Indiana.
Dodge, Anna, Indianapolis, Indiana.
Dolbear, A. Emerson, Bethany, West Virginia.

Edgar, George M., Franklin, Kentucky.
Edwards, William K., Terre Haute, Indiana.
Elliott, Thomas B., Indianapolis, Indiana.
English, Rose, Indianapolis, Indiana.
English, William E., Indianapolis, Indiana.
English, William H., Indianapolis, Indiana.

Farlow, W. G., Cambridge, Massachusetts.
Ferguson, James, Ashboro, Indiana.
Ficklin, Joseph, Columbia, Missouri.
Fishback, W. P., Indianapolis, Indiana.
Fisher, Clark, Trenton, New Jersey.
Fletcher, Ingram, Indianapolis, Indiana.
Fletcher, William B., Indianapolis, Indiana.

Garman, S. W., Holly Springs, Mississippi.
Gilpatrick, John L., Gosport, Indiana.
Gordon, George E., Indianapolis, Indiana.
Greer, James, Dayton, Ohio.

Hagar, Albert D., St. Louis, Missouri.
Harvey, Charles W., Greensburg, Indiana.
Hawley, C. T., Milwaukee, Wisconsin.
Hawley, R. E., Cincinnati, Ohio.
Hill, J. A., Greencastle, Indiana.
Hobbs, William Henry, Indianapolis, Indiana.
Holmes, Thomas, Merom, Indiana.
Hopkins, Frederick V., Baton Rouge, Louisiana.
Hosford, Charles E., Terre Haute, Indiana.
Hovey, Edmund O., Crawfordsville, Indiana.
Hovey, Mary F., Manhattan, Kansas.
Humphreys, A. W., New York, New York.
Hunt, Sarah E., Salem, Massachusetts.
Hunter, Morton C., Bloomington, Indiana.

Jackson, C. L., Cambridge, Massachusetts.

Kinder, Sarah, Indianapolis, Indiana.
Kneeland, Samuel, Boston, Massachusetts.

Landon, S. D., Attica, Indiana.
Locke, Erie, Indianapolis, Indiana.
Lyon, James A., Oxford, Mississippi.
Lyon, Sidney S., Jeffersonville, Indiana.

MacIntire, Thomas, Indianapolis, Indiana.
McChesney, Joseph H., Chicago, Illinois.
McDonald, J. D., Attica, Indiana.
McKeen, William R., Terre Haute, Indiana.
McRae, Hamilton S., Muncie, Indiana.
McWhorter, Tyler, Aledo, Illinois.
Malone, David R., Edinburg, Indiana.
Mendenhall, T. G., Columbus, Ohio.
Merritt, George, Indianapolis, Indiana.
Metcalf, Caleb B., Worcester, Massachusetts.
Mills, Isaac, F., Wabash, Indiana.
Mills, Joseph J. Wabash, Indiana.
Minshall, D. W., Terre Haute, Indiana.
Moore, Joseph, Richmond, Indiana.

Newman, John S., Indianapolis, Indiana.
Nutt, Cyrus, Bloomington, Indiana.

Owen, Richard, Bloomington, Indiana.

Parker, Lucy H., Cincinnati, Ohio.
Parvin, Theophilus, Indianapolis, Indiana.
Perkins, Jr., S. E., Indianapolis, Indiana.
Pierce, Henry D., Indianapolis, Indiana.
Poole, Henry S., Nova Scotia.
Poole, Joseph, Attica, Indiana.

Quincke, A. J., Oxford, Mississippi.

Read, Ezra, Terre Haute, Indiana.
Reed, Edmund B., London, Canada.
Richardson, F. C. A., Chicago, Illinois.
Robertson, Robert S., Fort Wayne, Indiana.
Rockwood, Charles G., Brunswick, Maine.
Rogers, Joseph G., Madison, Indiana.
Russell, L. W., Providence, Rhode Island.

Salter, James W., Richmond, Indiana.
Scott, Harvey D., Terre Haute, Indiana.
Seaman, Ezra C., Ann Arbor, Michigan.
Senter, Harvey S., Aledo, Illinois.
Sloan, John, New Albany, Indiana.
Smith, Eugene A., Tuscaloosa, Alabama.

Smith, T. Guilford, Philadelphia, Pennsylvania.
Spencer, John W., Paxton, Indiana.
Stearns, Thaddeus M., Indianapolis, Indiana.
Storrs, Henry E., Jacksonville, Illinois.
Stott, W. T., Franklin, Indiana.
Sutton, George, Aurora, Indiana.

Tappan, Eli T., Gambier, Ohio.
Taylor, Edward R., Cleveland, Ohio.
Taylor, Franklin, Indianapolis, Indiana.
Thomas, Norbourn, Terre Haute, Indiana.
Thompson, James, Bloomington, Indiana.
Tillman, Mrs. S. D., Jersey City, New Jersey.
Todd, Charles N., Indianapolis, Indiana.
Tomlinson, J. M., Indianapolis, Indiana.
Tuell, William B., Terre Haute, Indiana.

Vasey, George, Normal, Illinois.

Wahl, W. H., Philadelphia, Pennsylvania.
Walker, Joseph B., Louisville, Kentucky.
Walker, N. B., Arlington, Massachusetts.
Wheat, J. J., Oxford, Mississippi.
Whitney, Solon F., Watertown, Massachusetts.
Wiley, Philander, Greencastle, Indiana.
Williams, W. D., Macon, Georgia.
Wilson, Joseph R., Columbia, South Carolina.
Woodman, H. T., Dubuque, Iowa.
Wormley, Thomas G., Columbus, Ohio.
Wright, John C., Indianapolis, Indiana.
Wyckoff, William C., New York, New York.
Wylie, Theophilus A., Bloomington, Indiana.

Abbot, Elizabeth O., Providence, Rhode Island.
Holley, E. P., Niagara Falls, New York.

MEMBERS

WHO JOINED AT

THE TROY MEETING.

Barker, S. W., White Creek, New York.
Beattie, David, Troy, New York.
Blaisdell, A. H., Coeymans, New York.
Broome, Gordon, Montreal, Canada.

Chandler, C. F., New York, New York.
Childs, Walter C., Pittsburg, Pennsylvania.
Cooley, Le Roy C., Albany, New York.

Dodd, C. M., Williamstown, Massachusetts.

Evans, E. W., Ithaca, New York.

Fisher, Clark, Trenton, New Jersey.
Fisk, Richmond, Jr., Canton, New York.
Forsyth, James, Troy, New York.
Francis, C. S., Troy, New York.

Gale, Frederick, W., Troy, New York.
Gonzales, Juan A., Jr., New York, New York.
Greene, David M., Troy, New York.
Griswold, John A., Troy, New York.

Hagan, W. E., Troy, New York.
Harris, E. P. Amherst, Massachusetts.
Heimstreet, John W., Troy, New York.
Holley, A. L., Troy, New York.
Howe, E. C., New Baltimore, New York.
Hyatt, Jonathan S., Morrisania, New York.

Knapp, Frederick N., Plymouth, Massachusetts.

M'Conihe, Sarah S., Troy, New York.
Mann, Frank N., Troy, New York.
Merriam, William H., Troy, New York.

O'Donnell, Emma, Lansingburg, New York.

Parmenter, Jerome B., Troy, New York.
Pierce, H. A., Lansingburg, New York.

Seymour, Charles J., Binghampton, New York.
Shaler, N. S., Cambridge, Massachusetts.
Strawbridge, William C., Oxford, Pennsylvania.
Stuart, F. H., Hanover, New Hampshire.

Townsend, Martin I., Troy, New York.
Tracy, C. M., Lynn, Massachusetts.
Treat, Joseph, Vineland, New Jersey.

Walker, J. R., New Orleans, Louisiana.
Wheeler, Lewis C., Troy, New York.
Wilder, L., Hoosick Falls, New York.
Willard, John H., Troy, New York.
Willard, Sarah L., Troy, New York.
Williams, J. G., Detroit, Michigan.

MEMBERS

WHO JOINED AT

THE SALEM MEETING.

Adams, Samuel, Jacksonville, Illinois.
Allen, Joel A., Cambridge, Massachusetts.
Austin, E. L., Plymouth, Ohio.

Barnard, James M., Boston, Massachusetts.
Bliss, Porter C., New York, New York.
Boynton, John F., Syracuse, New York.

Chase, Pliny E., Philadelphia, Pennsylvania.
Cogswell, George, Bradford, Massachusetts.
Cogswell, William, Salem, Massachusetts.
Crampton, R. C., Jacksonville, Illinois.

Ellenwood, Charles N., San Francisco, California.
Endicott, William C., Salem, Massachusetts.

Foucou, Felix, Madison, Wisconsin.
Frothingham, Richard, Charlestown, Massachusetts.

Gilbert, G. K., Toledo, Ohio.
Goodell, Abner C., Jr., Salem, Massachusetts.

Hagar, D. B., Salem, Massachusetts.
Hartt, Charles F., Ithaca, New York.
Hoyt, J. W., Madison, Wisconsin.

Jasper, G. A., Charlestown, Massachusetts.
Johnson, Amos H., Salem, Massachusetts.

Loring, George B., Salem, Massachusetts.

Marden, George H., Charlestown, Massachusetts.

Rosseter, G. R., Marietta, Ohio.

Scofield, Samuel L., New York, New York.
Shepard, L. D., Boston, Massachusetts.
Smith, Isaac T., New York, New York.
Smith, Sidney I., New Haven, Connecticut.
Stevens, R. P., New York, New York.

Utley, Charles H., Buffalo, New York.

Valentine, Benjamin E., Brooklyn, New York.

Walker, Charles A., Chelsea, Massachusetts.
White, A. D., Ithaca, New York.
Woolworth, S. B., Albany, New York.

ADDRESS

OF

THOMAS STERRY HUNT,

EX-PRESIDENT OF THE ASSOCIATION.

MR. PRESIDENT, AND GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

IN coming before you this evening, my first duty is to announce the death of Professor William Chauvenet. This sad event was not unexpected, since, at the time of his election to the presidency of the Association, at the close of our meeting at Salem, in August, 1869, it was already feared that failing health would prevent him from meeting with us at Troy, in 1870. This, as you are aware, was the case, and I was therefore called to preside over the Association in his stead. In the autumn of 1869, he was compelled by illness to resign his position of Chancellor of the Washington University of St. Louis, and in December last died at the age of fifty years, leaving behind him a record to which science and his country may point with just pride. During his connection of fourteen years with the Naval Academy at Annapolis he was the chief instrument in building up that institution, which he left in 1859 to take the chair of Astronomy and Mathematics at St. Louis, where his remarkable qualities led to his selection, in 1862, for the post of chancellor of the university, which he filled with great credit and usefulness up to the time of his resignation.* It is not for me to pronounce the eulogy of Professor Chauvenet, to speak of his profound attainments in astronomy and mathematics, or of his published works, which have already taken rank as classics in the literature of these sciences. Others more familiar with his field of labor may in proper time and place attempt the task. All who knew him can, however, join with me in testifying to his excellencies

* Amer. Jour. Sci., III., i. 233.

as a man, an instructor, and a friend. In his assiduous devotion to scientific studies he did not neglect the more elegant arts, but was a skilful musician, and possessed of great general culture and refinement of taste. In his social and moral relations he was marked by rare elevation and purity of character, and has left to the world a standard of excellence in every relation of life which few can hope to attain.

In accordance with our custom, it becomes my duty in quitting the honorable position of president, which I have filled for the past year, to address you upon some theme which shall be germane to the objects of the Association. The presiding officer, as you are aware, is generally chosen to represent alternately one of the two great sections into which the members of the Association are supposed to be divided; viz., the students of the natural-history sciences on the one hand, and of the physico-mathematical and chemical sciences on the other. The arrangement by which, in our organization, geology is classed with the natural-history division, is based upon what may fairly be challenged as a somewhat narrow conception of its scope and aims. While theoretical geology investigates the astronomical, physical, chemical, and biological laws which have presided over the development of our earth, and while practical geology or geognosy studies its natural history, as exhibited in its physical structure, its mineralogy, and its paleontology, it will be seen that this comprehensive science is a stranger to none of the studies which are included in the plan of our Association, but rather sits like a sovereign, commanding in turn the services of all.

As a student of geology, I scarcely know with which section of the Association I should to-day identify myself. Let me endeavor rather to mediate between the two, and show you somewhat of the twofold aspect which geological science presents, when viewed respectively from the stand-points of natural history and of chemistry. I can hardly do this better than in the discussion of a subject which for the last generation has afforded some of the most fascinating and perplexing problems for our geological students; viz., the history of the great Appalachian mountain chain. Nowhere else in the world has a mountain system of such geographical extent and such geological complexity been studied by such a number of zealous and learned investigators, and no other, it may be confidently asserted, has furnished such vast and important

results to geological science. The laws of mountain structure, as revealed in the Appalachians by the labors of the brothers Henry D. and William B. Rogers, of Lesley, and of Hall, have given to the world the basis of a correct system of orographic geology,* and many of the obscure geological problems of Europe become plain when read in the light of our American experience. To discuss even in the most summary manner all of the questions which the theme suggests, would be a task too long for the present occasion, but I shall endeavor to-night, in the first place, to bring before you certain facts in the history of the physical structure, the mineralogy, and the paleontology of the Appalachians; and, in the second place, to discuss some of the physical, chemical, and biological conditions which have presided over the formation of the ancient crystalline rocks that make up so large a portion of our great eastern mountain system.

I. The Geognosy of the Appalachian System.

The age and geological relations of the crystalline stratified rocks of eastern North America have for a long time occupied the attention of geologists. A section across northern New York, from Ogdensburg on the St. Lawrence to Portland in Maine, shows the existence of three distinct regions of unlike crystalline schists. These are the Adirondacks to the west of Lake Champlain, the Green Mountains of Vermont, and the White Mountains of New Hampshire. The lithological and mineralogical differences between the rocks of these three regions are such as to have attracted the attention of some of the earlier observers. Eaton, one of the founders of American geology, at least as early as 1832, distinguished in his Geological Text-book (2d edition) between the gneiss of the Adirondacks and that of the Green Mountains. Adopting the then received divisions of primary, transition, secondary, and tertiary rocks, he divided each of these series into three classes, which he named carboniferous, quartzose, and calcareous; meaning by the first schistose or argillaceous strata, such as, according to him, might include carbonaceous matter. These three divisions, in fact, corresponded to clay, sand, and lime-rocks, and were supposed by him to be repeated in the same order in each series. This was apparently the first recognition of that law of cycles in sedimenta-

* Amer. Jour. Sci., II., xxx. 406.

tion upon which I afterwards insisted in 1863.* Without, so far as I am aware, defining the relations of the Adirondacks, he referred to the lowest or carboniferous division of the primary series the crystalline schists of the Green Mountains, while the quartzites and marbles at their western base were made the quartzose and calcareous divisions of this primary series. The argillites and sandstones, lying still farther westward, but to the east of the Hudson River, were regarded as the first and second divisions of the transition series, and were followed by its calcareous division, which seems to have included the limestones of the Trenton group; all of these rocks being supposed to dip to the westward, and away from the central axis of the Green Mountains. Eaton does not appear to have studied the White Mountains, or to have considered their geological relations. They were, however, clearly distinguished from the former by C. T. Jackson in 1844, when, in his report on the geology of New Hampshire, he described the White Mountains as an axis of primary granite, gneiss, and mica-schist, overlaid successively, both to the east and west, by what were designated by him Cambrian and Silurian rocks; these names having, since the time of Eaton's publication, been introduced by English geologists. While these overlying rocks in Maine were unaltered, he conceived that the corresponding strata in Vermont, on the western side of the granitic axis, had been changed by the action of intrusive serpentines and intrusive quartzites, which had altered the Cambrian into the Green Mountain gneiss, and converted a portion of the fossiliferous Silurian limestones of the Champlain valley into white marbles.† Jackson did not institute any comparison between the rocks of the White Mountains and those of the Adirondacks; but the Messrs. Rogers, in the same year, 1844, published an essay on the geological age of the White Mountains, in which, while endeavoring to show their Upper Silurian age, they speak of them as having been hitherto regarded as consisting exclusively of various modifications of granitic and gneissoid rocks, and as belonging "to the so-called primary periods of geologic time."‡ They, however, considered that these rocks had rather the aspect of altered paleozoic strata, and suggested that they might be, in part at least, of the age of the Clinton division of the New York

* Amer. Jour. Sci., II., xxxv. 166.
† Geology of New Hampshire, 160–162.
‡ Amer. Jour. Sci., II., i. 411.

system; a view which was supported by the presence of what were at the time regarded by the Messrs. Rogers as organic remains. Subsequently, in 1847,* they announced that they no longer considered these to be of organic origin, without, however, retracting their opinion as to the paleozoic age of the strata. Reserving to another place in my address the discussion of the geological age of the White Mountain rocks, I proceed to notice briefly the distinctive characters of the three groups of crystalline strata just mentioned, which will be shown in the sequel to have an importance in geology beyond the limits of the Appalachians.

I. *The Adirondack or Laurentide Series.* — The rocks of this series, to which the name of the Laurentian system has been given, may be described as chiefly firm granitic gneisses, often very coarse-grained, and generally reddish or grayish in color. They are frequently hornblendic, but seldom or never contain much mica, and the mica-schists (often accompanied with staurolite, garnet, andalusite, and cyanite), so characteristic of the White Mountain series, are wanting among the Laurentian rocks. They are also destitute of argillites, which are found in the other two series. The quartzites, and the pyroxenic and hornblendic rocks, associated with great formations of crystalline limestone, with graphite, and immense beds of magnetic iron ore, give a peculiar character to portions of the Laurentian system.

II. *The Green Mountain Series.* — The quartzo-feldspathic rocks of this series are to a considerable extent represented by a fine-grained petrosilex or eurite, though they often assume the form of a true gneiss, which is ordinarily more micaceous than the typical Laurentian gneiss. The coarse-grained, porphyritic, reddish varieties common to the latter are wanting in the Green Mountains, where the gneiss is generally of pale greenish and grayish hues. Massive stratified diorites, and epidotic and chloritic rocks, often more or less schistose, with steatite, dark-colored serpentines and ferriferous dolomites and magnesites also characterize this gneissic series, and are intimately associated with beds of iron ore, generally a slaty hematite, but occasionally magnetite. Chrome, titanium, nickel, copper, antimony, and gold are frequently met with in this series. The gneisses often pass into schistose micaceous quartzites, and the argillites, which abound, frequently assume a soft, unctuous character, which has acquired for them the name of talcose or

* Amer. Jour. Sci., II., v. 116.

nacreous slates, though analysis shows them not to be magnesian, but to consist essentially of a hydrous micaceous mineral. They are sometimes black and graphitic.

III. *The White Mountain Series.* — This series is characterized by the predominance of well-defined mica-schists, interstratified with micaceous gneisses. These latter are ordinarily light-colored, from the presence of white feldspar, and, though generally fine in texture, are sometimes coarse-grained and porphyritic. They are less strong and coherent than the gneisses of the Laurentian, and pass, through the predominance of mica, into mica-schists, which are themselves more or less tender and friable, and present every variety, from a coarse gneiss-like aggregate down to a fine-grained schist, which passes into argillite. The micaceous schists of this series are generally much richer in mica than those of the preceding series, and often contain a large proportion of well defined crystalline tables belonging to the species muscovite. The cleavage of these micaceous schists is generally, if not always, coincident with the bedding, but the plates of mica in the coarser-grained varieties are often arranged at various angles to the cleavage and bedding plane, showing that they were developed after sedimentation, by crystallization in the mass; a circumstance which distinguishes them from rocks derived from the ruins of these, which are met with in more recent series. The White Mountain rocks also include beds of micaceous quartzite. The basic silicates in this series are represented chiefly by dark-colored gneisses and schists, in which hornblende takes the place of mica. These pass occasionally into beds of dark hornblende-rock, sometimes holding garnets. Beds of crystalline limestone occasionally occur in the schists of the White Mountain series, and are sometimes accompanied by pyroxene, garnet, idocrase, sphene, and graphite, as in the corresponding rocks of the Laurentian, which this series, in its more gneissic portions, closely resembles, though apparently distinct geognostically. The limestones are intimately associated with the highly micaceous schists containing staurolite, andalusite, cyanite, and garnet. These schists are sometimes highly plumbaginous, as seen in the graphitic mica-schist holding garnets in Nelson, New Hampshire, and that associated with cyanite in Cornwall, Conn. To this third series of crystalline schists belong the concretionary granitic veins abounding in beryl, tourmaline, and lepidolite, and occasionally containing tinstone and columbite. Granitic veins, in the Laurentian gneisses frequently contain tour-

maline, but have not, so far as yet known, yielded the other mineral species just mentioned.*

Keeping in mind the characteristics of these three series, it will be easy to trace them southward, by the aid of the concise and accurate descriptions which Prof. H. D. Rogers has given us of the rocks of Pennyslvania. In his report on the geology of this State he has distinguished three districts of various crystalline schists, which are by him included together under the name of gneissic or hypozoic rocks. Of these districts, the most northern, or the South Mountain belt, to the north-west of the Mesozoic basin, is said to be the continuation of the Highlands of New York and New Jersey, which, crossing the Delaware near Easton, is continued southward through Pennsylvania and Maryland into Virginia, where it appears in the Blue Ridge. The gneiss of this district in Pennsylvania is described as differing considerably from that of the southernmost district, being massive and granitoid, often hornblendic, with much magnetic iron, but destitute of any considerable beds of micaceous, talcose, or chloritic slate, which mark the rocks of the southern district. These characters are sufficient to show that the gneiss of this northern district is lithologically as well as geognostically identical with that of the Highlands, and belongs like it to the Adirondack or Laurentian system of crystalline rocks. The gneiss of the middle district of Pennsylvania, to the south of the Mesozoic, but north of the Chester valley, is described by Rogers as resembling that of the South Mountain or northern district, and to consist chiefly of white feldspathic and dark hornblendic gneiss, with very little mica, and with crystalline limestones.

The gneiss of the third or southern district, that lying to the south of the Montgomery and Chester valleys, comes from beneath the Mesozoic of New Jersey, about six miles north-east of Trenton, and, stretching south-westward, occupies the southern border of Pennsylvania, extending into Delaware and Maryland. It is subdivided by Rogers into three belts; the first or southernmost of these, passing through Philadelphia, consists of alternations of dark hornblendic and highly micaceous gneiss, with abundance of mica-slate, sometimes coarse-grained, and at other times so fine-grained as to constitute a sort of whet-slate. To the north-westward the strata become still more micaceous, with garnets and

* Hunt, Notes on Granitic Rocks. Amer. Jour. Sci., III., i. 182.

beds of horneblende slate, till we reach the second subdivision, which consists of a great belt of highly talcose and micaceous schists, with steatite and serpentine, and is in its turn succeeded by a third, narrow belt resembling the less micaceous members of the first or southernmost subdivision. The micaceous schists of this region abound in staurolite, garnet, cyanite, and corundum, and are traversed by numerous irregular granitic veins containing beryl and tourmaline. All of these characters lead us to refer the gneiss of this southern district to the third or White Mountain series, with the exception of the middle subdivision, which presents the aspect of the second or Green Mountain series.

Above the hypozoic gneisses Rogers has placed his azoic or semi-metamorphic series, which is traceable from the vicinity of Trenton to the Schuylkill, along the northern boundary of the southern hypozoic gneiss district. This series is supposed by Rogers to be an altered form of the primal sandstones and slates, and is described as consisting of a feldspathic quartzite or eurite, containing in some cases porphyritic beds with crystals of feldspar and hornblende, together with various crystalline schists; including, in fact, the whole of the great serpentine belt of Montgomery, Chester, and Lancaster counties, with its steatites, hornblendic, dioritic, chloritic, and micaceous schists (often garnet-bearing), together with a band of argillite, affording roofing-slates. With this great series are associated chromic and titanic iron, and ores of nickel and copper. Veins of albite with corundum also intersect this series near Unionville. We are repeatedly assured by Rogers that these rocks so much resemble the underlying hypozoic gneiss, as to be readily confounded with them; and when compared with the latter, as displayed in the southern district, it is difficult to believe that we have in this so-called azoic or metamorphic series of the Montgomery and Chester valleys, any thing else than a repetition of these same crystalline schists which have been described along their southern boundary, representing the Green Mountain and the White Mountain series. We thus avoid the difficulty of supposing that we have in this region two sets of serpentinic rocks, and two of mica-schists, lithologically similar, but of widely different ages, — a conclusion highly improbable. It should be said that Rogers, in accordance with the notions then generally received, looked upon serpentine as an eruptive rock, which had altered the adjacent strata, converting the mica-schists into steatitic and chloritic rocks.

This so-called azoic series, according to Rogers, underlies the auroral limestone of Pennsylvania, thus apparently occupying the horizon of the primal paleozoic division or Potsdam series. We find, however, in his report on the geology of the State, no satisfactory evidence of the identity of the two series. On the contrary, a very different conclusion would seem to follow from certain facts there detailed. The azoic or so-called metamorphic primal strata are said to have a very uniform, nearly vertical, dip, or with high angles to the southward, while the micaceous and gneissic strata of the northern subdivision of the southern district of so-called hypozoic rocks, limiting these last to the south, present either minute local contortions or wide gentle undulations, with comparatively moderate dips, for the most part to the northward.* From this, I think we may infer that the nearly vertical strata must be, in truth, older underlying rocks, belonging, not to the paleozoic system, but to our second series of crystalline schists. We conclude, then, that while the gneisses to the north-west, and probably those along the south-east rim of the Mesozoic basin of Pennsylvania are Laurentian, the great valley southward to the Delaware is occupied by the rocks of the Green Mountain and White Mountain series. The same two types of rocks, extending to the north-east, are developed about New York city, in the mica-schists of Manhattan, and the serpentines of Staten Island and Hoboken; while in the range of the Highlands, the gneiss belt of the South Mountain crosses the Hudson river.

The three series of gneissic rocks which we have distinguished in our section to the northward, have, in south-eastern New York, as in Pennsylvania, been grouped together in the primary system, and may thence all be traced into Western New England. In Dr. Percival's Geological Report and Map of Connecticut, published in 1840, it will be seen that he refers to the gneiss of the Highlands two gneissic areas in Litchfield county; the one occupying parts of Cornwall and Ellsworth, and the other extending from Torrington, northward through Winchester, Norfolk, and Colebrooke into Berkshire county, Massachusetts. Farther investigations may confirm the accuracy of Percival's identification, and show the Laurentian age of these New England gneisses, a view which is apparently supported by the mineralogical characters of some of the rocks in this region. Emmons informs us that primary limestones with graphite

* Rogers, Geology of Pennsylvania, I., pp. 69–74, and 154–158.

(perhaps Laurentian) are met with in the Hoosic range in Massachusetts east of the Stockbridge (Taconic) limestones.

The rocks of the second series are traceable from south-western Connecticut northward to the Green Mountains in Vermont, and the micaceous schists and gneisses of the third or White Mountain series are found both to the east and the west of the Mesozoic valley in Connecticut and Massachusetts. They also occupy a considerable area in eastern Vermont, where they are separated from the White Mountain range by an outcrop of rocks of the second series. To the south-east of the White Mountains, along our line of section, the same mica-schists and gneisses, often with very moderate dips, extend as far as Portland, Maine, where they are interrupted by the outcropping of greenish chloritic and chromiferous schists, in nearly vertical beds, which appear to belong to the second series.

I find that the strata of the second series appear from beneath the carboniferous at Newport, Rhode Island, in a nearly vertical attitude, and also in the vicinity of Boston and Brighton, Saugus and Lynnfield. Their relations in this region to the gneisses with crystalline limestones of Chelmsford, &c., which I have referred to the Laurentian series,* have yet to be determined.

We have already mentioned that the crystalline rocks of Pennsylvania pass into Maryland and Virginia, where, as H. D. Rogers informs us, they appear in the mountains of the Blue Ridge. It remains to be seen whether the three types which we have pointed out in Pennsylvania are to be recognized in this region. A great belt of crystalline schists extends from Virginia through North and South Carolina, and into eastern Tennessee, where, according to Safford, these rocks underlie the Potsdam. It is easy, from the reports of Lieber on the geology of South Carolina, to identify in this State the two types of the Green Mountain and White Mountain series. The former, as described by him, consists of talcose, chloritic, and epidotic schists, with diorites, steatites, actinolite-rock, and serpentines. It may be noted that he still adheres to the notion of the eruptive origin of the last three rocks, which the observations of Emmons, Logan, and myself, in the Green Mountains, have shown to be untenable. These rocks in South Carolina generally dip at very high angles. The great gneissic area of Anderson and Abbeville districts is described by Lieber as consisting of fine-

* Amer. Jour. Sci., II., xlix. 75.

grained gray gneisses, with micaceous and hornblendic schists, and is cut by numerous veins of pegmatite, holding garnet, tourmaline, and beryl. These rocks, which have the character of the White Mountain series, appear, from the incidental observations to be found in Lieber's reports, to belong to a higher group than the chloritic and serpentinic series, and to dip at comparatively moderate angles.

Professor Emmons, whose attention was early turned to the geology of western New England, did not distinguish between the three types which we have defined, but, like Rogers in Pennsylvania, included all the crystalline rocks of that region in the primary system. It is to him, however, that we owe the first correct notions of the geological nature and relations of the Green Mountains. These, he has remarked, are often made to include two ranges of hills belonging to different geological series. The eastern range, including the Hoosic Mountain in Massachusetts, and Mount Mansfield in Vermont, he referred to the primary; which he described as including gneiss, mica-schist, talcose slate, and hornblende, with beds and veins of granite, limestone, serpentine, and trap. He declared, moreover, that there is no clear line of demarcation among the various schistose primary rocks; and cited, as an illustration, the passage into each other of serpentine, steatite, and talcose schist. His description of the crystalline rocks of this range will be recognized as comprehensive and truthful.

To the west of the hills of primary schist he placed his Taconic system, named from the Taconic hills, which run from north to south along the boundary line of New York and Massachusetts, and form a range parallel with the Green Mountains. The lower portions of the Taconic system, according to Emmons, are schistose rocks, made up from the ruins of the primary schists which lie to the east of them. Thus, the talcose schists of Berkshire are said to be regenerated rocks, belonging to the newer system, but showing the color and texture of the older talcose schists from which they were formed. How far this is true of these particular strata may be a question, for there is reason to believe that Emmons included among his Taconic rocks some beds belonging to the older crystalline series of the Green Mountains; yet it is not less true that the possibility of derived rocks of this kind is one which has been too much overlooked by geologists. Emmons elsewhere remarks that while the talcose slates of the primary are associated with steatite and with hornblende, these are never found in the Taconic

rocks, and also, that epidote, actinolite, titanium (rutile), &c., which are characteristic minerals of the primary, are wanting in the Taconic system.

The statements of Emmons on this point were sufficiently explicit; he included in the primary system all of the crystalline schists of the Green Mountains, except certain talcose and micaceous beds, which he supposed to be composed from the ruins of similar strata in the primary, and to constitute, with a great mass of other rocks, the Taconic system; which was, in its turn, unconformably overlaid by the Potsdam sandstone and calciferous sandrock of the New York system. His views have, however, been misunderstood by more than one of his critics; thus, Mr. Marcou, while defending the Taconic system, makes it to include the three groups just mentioned, viz.: I. the Green Mountain gneiss; II. the Taconic strata as defined by Emmons; and III. the Potsdam sandstone,* thus uniting in one system the crystalline schists and the overlying uncrystalline fossiliferous sediments, in direct opposition to the plainly expressed teachings of Emmons, as laid down in his report on the Geology of the Northern District of New York, and later, in 1846,† in his work on the Taconic system.

In the geological survey of the State of New York, the rocks of the Champlain division, including the strata from the base of the Potsdam sandstone to the summit of the Loraine or Hudson River shales, had, by his colleagues, been looked upon as the lowest of the paleozoic system. Professor Emmons, however, was led to regard the very dissimilar strata of the Taconic hills as constituting a distinct and more ancient series. A similar view had been held by Eaton, who placed, as we have already seen, above the crystalline schists of the Green Mountains, his primary quartzose and calcareous formations, followed to the westward by transition argillites and sandstones, which latter appear to have corresponded to the Potsdam sandstone of New York. Emmons, however, gave a greater form and consistency to this view, and endeavored to sustain it by the evidence of fossils, as well as by structure. The Taconic system, as defined by him, may be briefly described as a series of uncrystalline fossiliferous sediments, reposing unconformably on the crystalline schists of the Green Mountains, and partly made up of their ruins; while it is, at the same time, overlaid uncon-

* Proc. Bost. Nat. Hist. Soc., Nov. 6, 1861, and Amer. Jour. Sci., II., xxxiii. 282.

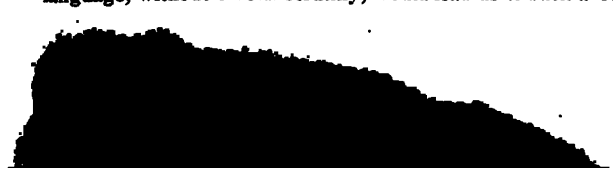
† Loc. cit., p. 139, and Agricult. N. York, I. 58.

formably by the Potsdam and calciferous formations of the Champlain division, and constitutes the true base of the paleozoic column, — thus occupying the position of the British Cambrian.

Although he claimed to have traced this Taconic system throughout the Appalachian chain from Maine to North Carolina, it is along the confines of Massachusetts and New York that its development was most minutely studied. He divided it into a lower and an upper division, and estimated its total thickness at not less than thirty thousand feet, consisting, in the order of deposition, of the following members: — 1. Granular quartz; 2. Stockbridge limestone; 3. Magnesian slate; 4. Sparry limestone; 5. Roofing-slate, graptolitic; 6. Silicious conglomerate; 7. Taconic slate; 8. Black slate. The apparent order of superposition differs from this; and it was conceived by Professor Emmons that, during the accumulation of these Taconic rocks, the Green Mountain gneiss, which formed the eastern border of the basin, was gradually elevated so as to bring successively the older members above the ocean from which the sediments were being deposited. From this it resulted that the upper members of the system, such as the black slates, were confined to a very narrow belt, and never extended far eastward; although he admits that denudation may have removed large portions of these upper beds. At a subsequent period, a series of parallel faults, with upthrows on the eastern side, is supposed to have broken the strata, given them an eastward dip, and caused the newer beds to pass successively beneath the older ones, thus producing an *apparently inverted succession*, and making their present seeming order of superposition completely deceptive. In speaking of this supposed arrangement of the members of his Taconic system, Emmons alluded to them as "inverted strata;" while by Mr. Marcou the strata were said to be "overturned on each side of the crystalline and eruptive rocks which occupy the centre of the chain, producing thus a fan-shaped structure," &c.* I have elsewhere shown that this notion, though to some extent countenanced by his vague and inaccurate use of terms, was never entertained by Emmons, whose own view, as defined in his *Taconic System* (p. 17),† is that just explained.

* Comptes Rendus de l'Acad., LIII. 804.

† See my farther discussion of the matter, Amer. Jour. Sci., II., xxxii. 427, xxxiii. 135, 281. It is by an oversight that I have, in the latter volume, page 136, represented Barrande as sharing the misconception of Marcou, although his language, without careful scrutiny, would lead us to such a conclusion. In fact,



The view of Emmons, that there exists at the western base of the Green Mountains older fossiliferous series underlying the Potsdam, met with general opposition from American geologists. In May, 1844, H. D. Rogers, in his address as President, before the American Association of Geologists, then met at Washington, criticised this view at length, and referred to a section from Stockbridge, Massachusetts, to the Hudson River, made by W. B. Rogers and himself, and by them laid before the American Philosophical Society, in January, 1841. They then maintained that the quartz-rock of the Hoosic range was Potsdam, the Berkshire marble identical with the blue limestone of the Hudson valley, and the associated micaceous and talcose schists, altered strata of the age of the slates at the base of the Apallachian system; that is to say, primal in the nomenclature of the Pennsylvanian survey.

In 1843 Mather had asserted the Champlain age of the same crystalline rocks, and claimed that the whole of the division was there represented, including the Potsdam, the Hudson River group, and the intermediate limestones.* The conclusion of Mather was cited with approbation by Rogers, who apparently adopted it, and claimed that Hitchcock held a similar view. It will be seen that these geologists thus united in one group the schists of the Hoosic range (regarded by Emmons as primary) with those of the Taconic range, and referred both to the age of the Champlain division, the whole of which was supposed to be included in the group.

In the same address Professor Rogers raised a very important question. Having referred to the Potsdam sandstone, which on Lake Champlain forms the base of the paleozoic system, he inquires, "Is this formation then the lowest limit of our Appalachian masses generally, or is the system expanded downward in other districts by the introduction beneath it of other conformable sedimentary rocks?" He then proceeded to state that from the Susquehanna River, south-westward, a more complex series appears at the base of the lower limestone than to the north of the Schuylkill, and in some parts of the Blue Ridge he includes in the primal

in the Bull. Soc. Geol. de France (II., xviii. 261), in an elaborate study of the Taconic question, Barrande heads a section thus, "*Renversement conçu pour tout un système,*" and then proceeds to show that the *renversement* or *overturn* is only apparent, by explaining, in the language of Emmons, the view already set forth above.

* Geology of the Southern District of New York, p. 488.

division (beneath the calciferous sandrock) "at least four independent and often very thick deposits, constituting one general group, in which the Potsdam or white sandstone (with Scolithus) is the second in descending order. This sandstone is overlaid by many hundred feet of arenaceous and ferriferous fucoidal slate, and underlaid by coarse sandy shales and flagstones; below which, in Virginia and East Tennessee, is a series of heterogeneous conglomerates, which rest on a great mass of crystalline strata. The accuracy of these statements is confirmed by Safford, who, in his recent Report on the Geology of Tennessee (1869), places at the base of the column a great series of crystalline schists, apparently representatives of those of south-eastern Pennsylvania. Upon these repose what Safford designates as the Potsdam group, including, in ascending order, the Ococee slates and conglomerates, estimated at 10,000 feet, and the Chilhowee shales and sandstones, 2,000 feet or more, with fucoids, worm-burrows, and Scolithus. These are conformably overlaid by the Knoxville division, consisting of fucoidal sandstones, shales, and limestones, the latter two holding fossils of the age of the calciferous sandrock. It is noteworthy that these rocks are greatly disturbed by faults, and that in Chilhowee Mountain the lower conglomerates are brought on the east against the carboniferous limestone, by a vertical displacement of at least 12,000 feet. The general dip of all these strata, including the basal crystalline schists, is to the south-east.

The primal paleozoic rocks of the Blue Ridge were then by Rogers, as now by Safford, looked upon as wholly of Potsdam age, including the Scolithus sandstone as a subordinate member, so that the strata beneath this were still regarded as belonging to the New York system. Hence, while Rogers inquires whether the Taconic system "may not along the western border of Vermont and Massachusetts include also some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone,"* he would still embrace these lower strata in the Champlain division.

Thus we see that at an early period the rocks of the Taconic system were, by Rogers and Mather, referred to the Champlain division of the New York system, a conclusion which has been sustained by subsequent observations. Before discussing these, and

* Amer. Jour. Sci., I., xlvii. 152, 153.

their somewhat involved history, we may state two questions which present themselves in connection with this solution of the problem. First, whether the Taconic system, as defined by Emmons, includes the whole or a part of the Champlain division; and second, whether it embraces any strata older or newer than the members of this portion of the New York system. With reference to the first question, it is to be remarked that in their attempts to compare the Taconic rocks with those of the Champlain division, as seen farther to the west, observers were led by lithological similarities to identify the upper members of the latter with certain portions of the Taconic. In fact, the Trenton limestone, with the Utica slates and the Loraine or Hudson River shales, making together the upper half of the Champlain division (in which Emmons, moreover, included the overlying Oneida and Medina conglomerates and sandstones), have in New York an aggregate thickness of not less than three or four thousand feet, and offer many lithological resemblances to the great mass of sediments at the western base of the Green Mountains, to which the name of Taconic had been applied. It is curious to find that Emmons, in 1842, referred to the Medina the red sandrock of the east shore of Lake Champlain, since shown to be Potsdam; and, moreover, placed the Sillery sandstone of the neighborhood of Quebec at the summit of the Champlain division, as the representative of the Oneida conglomerate; while at the same time he noticed the great resemblance which this sandstone, with its adjacent limestones, bore to similar rocks on the confines of Massachusetts, already referred by him to the Taconic system.*

This view of Emmons, as to the Quebec rocks, was adopted by Sir William Logan, when, a few years afterwards, he began to study the geology of that region. The sandstone of Sillery was described by him as corresponding to the Oneida or Shawangunk conglomerate, while the limestones and shales of the vicinity, which were supposed to underlie it, were regarded as the representatives of the Trenton, Utica, and Hudson River formations.† By following these rocks along the western base of the Appalachians into Vermont and Massachusetts, they were found to be a continuation of the Taconic system, which Sir William was thus led to refer to the upper half of the Champlain division, as had

* Geol. Northern District of New York, pp. 124, 125.

† Geol. Survey of Canada, 1847–48, pp. 27, 57; and Amer. Jour. Sci., II., ix. 12.

already been done by Professor Adams in 1847.* As regards the crystalline strata of the Appalachians, in this region, he, however, rejected the view of Emmons, and maintained that put forward by the Messrs. Rogers in 1841, viz., that they, instead of being older rocks, were but these same upper formations of the Champlain division in an altered condition; a view which was maintained during several years in all of the publications of those connected with the geological survey of Canada.

This conclusion, so far as regards the age of the unaltered fossiliferous rocks from Quebec to Massachusetts, was supposed to be confirmed by the evidence of organic remains found in them in Vermont. Mr. Emmons had described, as characteristic of the upper part of the Taconic system, two crustaceans, to which he gave the names of *Atops trilineatus* and *Elliptocephalus asaphoides;* the other fossils noticed by him being graptolites, fucoids, and what were apparently the marks of annelids. In 1847, Professor James Hall, in the first volume of his Paleontology, declared the Atops of Emmons to be identical with *Triarthrus* (*Calymene*) *Beckii*, a characteristic fossil of the Utica slate; while the Elliptocephalus was referred by him to the genus *Olenus*, now known to belong to the primordial fauna of Sweden, where it is found in slates lying beneath the orthoceratite limestone, and near the base of the paleozoic series. Although, as it now appears, the geological horizon of the Olenus slates was well known to Hisinger, this author, in his classic work, *Lethæa Suecica*, published in 1837, represents, by some unexplained error, these slates as overlying the orthoceratite limestone, which is the equivalent of the Trenton limestone of the Champlain division. Hence, as Mr. Barrande has remarked, Hall was justified, by the authority of Hisinger's published work, in assigning to the Olenus slates of Vermont a position above that limestone, and in placing them, as he then did, on the horizon of the Hudson River or Loraine shales. The double evidence afforded by these two fossil forms in the rocks of Vermont served to confirm Sir William Logan in placing in the upper part of the Champlain division the rocks which he regarded as their stratigraphical equivalents near Quebec, and which, as we have seen, had some years before been, by Emmons himself, assigned to the same horizon. The remarkable compound graptolites which occur in the shales of Pointe Levis, opposite Quebec, were described by

* Amer. Jour. Sci., II., v. 108.

Professor James Hall, in the report of the Geological Survey of Canada for 1857, and were then referred to the Hudson River group; nor was it until August, 1860, that Mr. Billings described from the limestones of this same series, at Pointe Levis, a number of trilobites, among which were several species of Agnostus, Dikelocephalus, Bathyurus, &c., constituting a fauna whose geological horizon he decided to be in the lower part of the Champlain division.

Just previous to this time, in the Report of the Regents of the University of New York, for 1859, Professor Hall had described and figured by the name of Olenus two species of trilobites from the slates of Georgia, Vermont, which Emmons had wrongly referred to the genus Paradoxides. They were at once recognized by Barrande, who called attention to their primordial character, and thus led to a knowledge of their true stratigraphical horizon, and to the detection of the singular error in Hisinger's book, already noticed, by which American geologists had been misled.* They have since been separated from Olenus, and by Professor Hall referred to a new and closely related genus, which he has named Olenellus, and which is now regarded as belonging to the horizon of the Potsdam sandstone, to which we shall presently advert.

Farther studies of the fossiliferous rocks near Quebec showed the existence of a mass of sediments, estimated at about 1,200 feet, holding a numerous fauna, and corresponding to a great development of strata about the age of the Calciferous and Chazy formations, or more exactly to a formation occupying a position between these two, and constituting, as it were, beds of passage between them. In this new formation were included the graptolites already described by Hall, and the numerous crustacea and brachiopoda described by Billings, all of which belong to the Levis slates and limestones. To these and their associated rocks Sir William Logan then gave the name of the Quebec group, including, besides the fossiliferous Levis formation, a great mass of overlying slates, sandstones, and magnesian limestones, hitherto without fossils, which have been named the Lauzon rocks, and the Sillery sandstones and shales, which he supposed to form the summit of the group, and which had afforded only an Obolella and two species of Lingula;† the volume of the whole group being about 7,000 feet.

* For the correspondence on this matter between Barrande, Logan, and Hall, see Amer. Jour. Sci., II., xxxi., 210–226.

† See Billings, Paleozoic Fossils of Canada, p. 69.

The paleontological evidence thus obtained by Billings and by Hall, both from near Quebec and in Vermont, led to the conclusion that the strata of these regions, so much resembling the upper members of the Champlain division, were really a great development, in a modified form, of some of its lower portions. Their apparent stratigraphical relations were explained by Logan by the supposition of "an overturned anticlinal fold, with a crack and a great dislocation running along the summit, by which the Quebec group is brought to overlie the Hudson River group. Sometimes it may overlie the overturned Utica formation, and in Vermont points of the overturned Trenton appear occasionally to emerge from beneath the overlap." He, at the same time, declared that "from the physical structure alone, no person would suspect the break that must exist in the neighborhood of Quebec, and, without the evidence of fossils, every one would be authorized to deny it."*

The rocks from western Vermont, which had furnished to Hall the species of Olenellus, have long been known as the Red sandrock, and, as we have seen, were by Emmons, in 1842, referred to the age of the Medina sandstone, a view which the late Professor Adams still maintained as late as 1847.† In the mean time Emmons had, in 1855, declared this rock to represent the Calciferous and Potsdam formations, the brown sandstones of Burlington and Charlotte, Vermont, being referred to the latter.‡ This conclusion was confirmed by Billings, who, in 1861, after visiting the region and examining the organic remains of the Red sandrock, assigned to it a position near the horizon of the Potsdam.§ Certain trilobites found in this Red sandrock by Adams, in 1847, were by Hall recognized as belonging to the European genus *Conocephalus* (= *Conocephalites* and *Conocoryphe*), whose geological horizon was then undetermined.‖ The formation in question consists in great part of a red or mottled granular dolomite, associated with beds of fucoidal sandstone, conglomerates, and slates. These rocks were carefully examined by Logan in Swanton, Vermont, where, according to him, they have a thickness of 2,200 feet, and include towards their base a mass of dark

* Logan's letter to Barrande, Amer. Jour. Sci., II., xxxi. 218. The true date of this letter was December 31, 1860, but, by a misprint, it is made 1831.

† Adams, Amer. Jour. Sci., II., v. 108.

‡ Emmons, American Geology, II., 128.

§ Amer. Jour. Sci., II., xxxii. 232.

‖ Ibid., II., xxxiii. 374.

colored shales, holding Olenellus with Conocephalites, Obolella, &c.; *Conocephalites Teucer*, Billings, being common to the shales and the red sandy beds.* Many of these fossils are also found at Troy and at Bald Mountain, New York, where they accompany the Atops of Emmons, now recognized by Billings as a species of Conocephalites.

A similar condition of things extends north-eastward along the Appalachian region. On the south side of the St. Lawrence, below Quebec, a great thickness of limestones, sandstones, and slates, formerly referred to the Quebec group, is now regarded by Billings as, in part at least, of the Potsdam formation; while on the coast of Labrador, and in northern Newfoundland, the same formation, characterized by the same fossils as in Vermont, is largely developed, attaining in some parts, according to Murray, a thickness of 3,000 feet or more. Along the northern coast of the island it is nearly horizontal, and appears to be conformably overlaid by about 4,000 feet of fossiliferous strata, representing the Calciferous sandrock and the succeeding Levis formation.

Mr. Billings has described a section from the Laurentian of Crown Point, New York, to Cornwall, Vermont, from which it appears that to the eastward of a dislocation which brings up the Potsdam to overlie the higher members of the Champlain division, the Potsdam is itself overlaid, at a small angle, by a great mass of limestones representing the Calciferous, and having at the summit some of the characteristic fossils of the Levis formation. Next in ascending order are not less than 2,000 feet of limestones with Trenton fossils (embracing probably the Chazy division), while to the east of this the Levis again appears, including the white Stockbridge limestones.† We have here an evidence that the augmentation in volume observed in the lower members of the Champlain division in the Appalachian region extends to the Trenton, which to the west of Lake Champlain is represented, the Chazy included, by not more than 500 feet of limestone. The Potsdam, in the latter region, consists of from 500 to 700 feet of sandstone, holding Conocephalites and Lingulella, and overlaid by 300 feet of magnesian limestone, the so-called Calciferous sandrock. In the valley of the Mississippi these two formations, in Iowa, Missouri, and Texas, are represented by from 800 to 1,300 feet of sandstones and mag-

* Geology of Canada, 1863, p. 281. Amer. Jour. Sci., II., xlvi. 224.

† Amer. Jour. Sci., II., xlvi. 227.

nesian limestones, while in the Black Hills of Nebraska, according to Hayden, the only representative of these lower formations is about one hundred feet of sandstone, holding Potsdam fossils.*

In striking contrast to this it has been shown that along the Appalachian range, from Newfoundland to Tennessee, these lower formations are represented by from 8,000 to 15,000 feet of fossiliferous sediments. It has been suggested by Logan that these widely-differing conditions represent deep-sea accumulations on the one hand, and the deposits from a shallow sea which covered a submerged continental plateau on the other; the sediments in the two areas being characterized by a similar fauna, though differing greatly in lithological characters and in thickness. To this we may add that the continental area, being probably submerged and elevated at intervals, became overlaid with beds which represent only in a partial and imperfect manner the great succession of strata which were being accumulated in the adjacent ocean.†

In a paper, which I hope to present to the geological section during the present meeting of the Association, it will be shown from a study of the rocks of the Ottawa basin that the typical Champlain division not only presents important paleontological breaks, but evidences of statigraphical discordance at more than one horizon over the continental area, which, as the result of widely spread movements, might be supposed to be represented in the Appalachian region. In the latter Logan has already observed that the absence of all but the highest beds of the Levis along the eastern limit of the Potsdam, near Swanton, Vermont, while the whole thickness of them appears a little farther westward, makes it probable that there is a want of conformity between the two; and I have in this connection insisted upon the entire absence in this locality of the Calciferous, which is met with a little farther south in the section just mentioned, as another evidence of the same unconformity.‡ There are also, I think, reasons for suspecting another stratigraphical break at the summit of the Quebec group, in which case many problems in the geological structure of this region will be much simplified.

It should be remembered that the conditions of deposition in some areas have been such that accumulations of strata, corre-

* Amer. Jour. Sci., II., xxv. 439; xxxi. 234.
† Ibid., II., xlvi. 225.
‡ Ibid., II., xlvi. 225.

sponding to long geologic periods, and elsewhere marked by stratigraphical breaks, are arranged in conformable superposition; and, moreover, that movements of elevation and depression have even caused great paleontological breaks, which over considerable areas are not marked by any apparent discordance. Thus the remarkable break in the fauna between the Calciferous and the Chazy is not accompanied by any noticeable discordance in the Ottawa basin, and in Nebraska, according to Hayden, the Potsdam, Carboniferous, Jurassic, and Cretaceous formations are all represented in about 1,200 feet of conformable strata.* In Sweden the whole series, from the base of the Cambrian to the summit of the Upper Silurian, appears as a conformable sequence, while in North Wales, although there is no apparent discordance from the base of the Cambrian to the summit of the Lingula flags, stratigraphical breaks, according to Ramsay, probably occur both at the base and the summit of the Tremadoc slates,† which are considered equivalent to the Levis formation.

We have seen that, according to Logan, a dislocation a little to the north of Lake Champlain causes the Quebec group to overlie the higher members of the Champlain division. The same uplift, according to him, brings up, farther south, the Red sandrock of Vermont, which, to the west of the dislocation, rests upon the upturned and inverted strata of various formations from the Calciferous sandrock to the Utica and Hudson River shales. These latter, according to him, are seen to pass for considerable distances beneath nearly horizontal layers of the Red sandrock, the Utica slate, in one case, holding its characteristic fossil, *Triarthrus Beckii*. This relation, which is well shown in a section at St. Albans, figured by Hitchcock,‡ was looked upon by Emmons and by Adams as evidence that the Red sandrock was the representative of the Medina sandstone of the New York system. When, however, the former had recognized the Potsdam age of the sandrock, with its Olenellus, which he supposed to be Paradoxides, this condition of things was conceived to be an evidence of the existence beneath the Potsdam of an older and unconformable fossiliferous series already mentioned.

The objections made by Emmons to Rogers's view of the Cham-

* Amer. Jour. Sci., II., xxv. 440.
† Quar. Geol. Journal, xix. p. xxxvi.
‡ Geology of Vermont, p. 874.

plain age of the Taconic rocks were threefold: first, the great differences in lithological characters, succession, and thickness, between these and the rocks of the Champlain division as previously known in New York; second, the supposed unconformable infraposition of a fossiliferous series to the Potsdam; and third, the distinct fauna which the Taconic rocks were supposed to contain. The first of these is met by the fact now established that in the Appalachian region the Champlain division is represented by rocks having, with the same organic remains, very different lithological characters, and a thickness tenfold greater than in the typical Champlain region of Northern New York. The second objection has already been answered by showing that the rocks which pass beneath the Potsdam are really newer strata belonging to the upper part of the division, and contain a characteristic fossil of the Utica slate. As to the third point, it has also been met, so far as regards the Atops and Elliptocephalus, by showing these two genera to belong to the Potsdam formation. If we inquire farther into the Taconic fauna we find that the Stockbridge limestone (the Eolian limestone of Hitchcock), which was placed by Emmons near the base of the lower Taconic (while the Olenellus slates are near the summit of the Upper Taconic), is also fossiliferous, and contains, according to the determinations of Professor Hall, species belonging to the genera Euomphalus, Zaphrentis, Stromatopora, Chaetetes, and Stictopora.* Such a fauna would lead to the conclusion that these limestones, instead of being older, were really newer than the Olenellus beds, and that the apparent order of succession was, contrary to the supposition of Emmons, the true one. This conclusion was still farther confirmed by the evidence obtained in 1868 by Mr. Billings, who found in that region a great number of characteristic species of the Levis formation, many of them in beds immediately above or below the white marbles,† which latter, from the recent observations of the Rev. Augustus Wing, in the vicinity of Rutland, Vermont, would seem to be among the upper beds of the Potsdam formation. Thus, while some of the Taconic fossils belong to the Potsdam and Utica formations, the greater number of them, derived from beds supposed to be low down in the system, are shown to be of the age of the Levis formation. There is, therefore, at present no evi-

* Geology [illegible] ci., II., xxxiii. 419.

† Amer[illegible]

dence of the existence, among the unaltered sedimentary rocks of the western base of the Appalachians in Canada or New England, of any strata more ancient than those of the Champlain division, to which, from their organic remains, the fossiliferous Taconic rocks are shown to belong.

Mr. Billings has, it is true, distinguished provisionally what he has designated an upper and a lower division of the Potsdam, and has referred to the latter the Red sandrock with the Olenellus slates of Vermont, together with beds holding similar fossils at Troy, New York, and along the Straits of Bellisle in Labrador and Newfoundland; the upper division of the Potsdam being represented by the basal sandstones of the Ottawa basin and of the Mississippi valley.* In the present state of our knowledge of the local variations in sediments and in their fauna dependent on depth, temperature, and ocean currents, Billings, however, conceives that it would be premature to assert that these two types of the Potsdam do not represent synchronous deposits.

The base of the Champlain division, as known in the Potsdam formation of New York, of the Mississippi valley, and the Appalachian belt, does not, however, represent the base of the paleozoic series in Europe. The Alum slates in Sweden are divided into two parts, an upper or Olenus zone, and a lower or Conocoryphe zone, as distinguished by Angelin. The latter is characterized by the genus Paradoxides, which also occupies a lower division in the primordial paleozoic rocks of Bohemia (Barrande's stage C), the greater part of which are regarded as the equivalent of the Olenus zone of Sweden and the Potsdam of North America. The Lingula flags of Wales belong to the same horizon, and it is at their base, in strata once referred to the Lower Lingula flags, that the Paradoxides is met with. These strata, for which Hicks and Salter, in 1865, proposed the name of the Menevian group, are regarded as corresponding to the lower division of the Alum slates, and, like it, contain a fauna not yet recognized in the basal rocks of the New York system. We here approach the debatable land between the Cambrian and the Silurian of the British geologists. The Cambrian, as originally claimed by Sedgwick, included in its upper division the Middle and Upper Lingula flags, with the overlying Tremadoc slates, to the base of the Llandeilo rocks, and may be regarded as equivalent to the Potsdam, Calciferous, and Levis

* Report Geol. of Canada, 1863–66, p. 236.

formations; while in the Lower Cambrian were embraced the Lower Lingula flags and the Upper and Lower Longmynd rocks, corresponding respectively to the Harlech grits and the Llanberis slates. A portion of the Cambrian has, however, been claimed for the Silurian by Murchison, who draws the dividing line at the top of the Longmynd rocks, leaving the three divisions of the Lingula flags in the Silurian. Lyell, on the contrary, remarks that the Menevian beds, which were, on lithological grounds, made by Sedgwick a part of the Lower Lingula flags, have been shown by Hicks and Salter to be very distinct from these paleontologically; and, while he includes the Menevian in the Lower Cambrian, refers the whole of the Lingula flags to the Upper Cambrian.

Lyell, therefore, admits the whole of the Cambrian system as originally defined by Sedgwick, and the same classification is now adopted by Linarsson, in Sweden, where, in Westrogothia, the Cambrian rocks (resting unconformably on the crystalline schists, to be noticed farther on), are overlaid conformably by the orthoceratite limestones, which are by him regarded as forming the base of the Silurian, and as the equivalent of the Llandeilo rocks of Wales. The total thickness of these lower rocks in Sweden, including the representatives of the Lingula flags, the Menevian beds, and an underlying fucoidal (Eophyton) sandstone, is only three hundred feet, while the first two divisions in Wales have a thickness of five to six thousand, and the Harlech grits and Llanberis slates (including the Welsh roofing-slates beneath) amount to eight thousand feet additional. Recent researches show that these lower rocks in Wales contain an abundant fauna, extending downward some 2,800 feet from the Menevian to the very base of strata regarded as the representatives of the Harlech grits. The brachiopoda of the Harlech beds appear identical with those of the Menevian, but new species of *Conocephalites*, *Microdiscus*, and *Paradoxides* are met with, besides a new genus, *Plutonia*, allied to the last mentioned. Mr. Hicks, to whom we owe these discoveries,* remarks that the Menevian gives us, for the present, a well marked paleontological horizon for the summit of the Cambrian, corresponding with the Lower Cambrian as defined by Sedgwick.

The Upper Cambrian in North America would thus include the lower half of the Champlain division, from the base of the Potsdam

* Geol. Mag., V. 306; and Rep. Brit. Assoc., 1868, p. 69; also Harkness and Hicks in Nature, Proc. Geol. Soc., May 10, 1871.

to the summit of the Levis (including perhaps the Chazy), while the Lower Cambrian (the Cambrian of Murchison and Hicks) is represented by the strata-holding Paradoxides in Newfoundland, New Brunswick, and eastern Massachusetts. Although no strata marked by these fossils have yet been found in the Appalachians, it is not improbable that such may yet be met with. In May, 1861, I called attention to the fact that beds of quartzose conglomerate at the base of the Potsdam, in Hemmingford, near the outlet of Lake Champlain, on its western side, contain fragments of green and black slates, "showing the existence of argillaceous slates before the deposition of the Potsdam sandstone."* The more ancient strata, which furnished these slaty fragments to the Potsdam conglomerate, have, perhaps, been destroyed, or are concealed, but they or their equivalents may yet be discovered in some part of the great Appalachian region. They should not, however, be called Taconic, but receive the prior designation of Cambrian, unless, indeed, it shall appear that the source of these slate fragments was the more argillaceous beds of the still older Huronian schists. Emmons regarded his Taconic system as the equivalent of the Lower Cambrian of Sedgwick, but when, in 1842, Murchison announced that the name of Cambrian had ceased to have any zoölogical significance, being identical with Lower Silurian,† Emmons conceiving, as he tells us, that all Cambrian rocks were not Silurian, instead of maintaining Sedgwick's name, which with the progress of paleontological study is assuming a great zoölogical importance, devised the name of Taconic, as synonymous with Lower Cambrian;‡ although, as we have seen, there is as yet no paleontological evidence to identify any portion of the Taconic strata with the well-defined Lower Cambrian rocks of our eastern shores.

The crystalline infra-Silurian strata, to which the name of the Huronian series has been given by the Geological Survey of Canada, have sometimes been called Cambrian, from their resemblance to certain rocks in Anglesea, which have been looked upon as altered Cambrian. The typical Cambrian rocks of Wales, down to their base, are, however, uncrystalline sediments, and, as pointed out by Dr. Bigsby, in 1863,§ are not to be confounded with the

* Amer. Jour. Sci., II., xxxi. 404.

† Proc. Geol. Soc., London, III. 642.

‡ Emmons, Geol. N. District of New York, 162; and Agric. of New York, I. 49.

§ Quar. Jour. Geol. Soc., XIX. 36.

Huronian, which he regarded as equivalent to the second division of the so-called azoic rocks of Norway, the *Urschiefer*, or primitive schists, which in that country rest unconformably on the primitive gneiss (*Urgneiss*), and are in their turn overlaid unconformably by the fossiliferous Cambrian strata. This second, or intermediate series, in Norway, is characterized by eurites, micaceous, chloritic, and hornblendic schists, with diorites, steatite, and dark-colored serpentines, generally associated with chrome, and abounds in ores of copper, nickel, and iron. In its mineralogical and lithological characters, the Urschiefer corresponds with what we have designated the second series of crystalline schists. It is, in Norway, divided into a lower or quartzose division, marked by a predominance of quartzites, conglomerates, and more massive rocks, and an upper and more schistose division. Macfarlane, who was familiar with the rocks of Norway, after examining both the Huronian of Lake Superior and the crystalline strata of the Green Mountains, had already, in 1862, declared his opinion that both of these were representatives of the Norwegian Urschiefer,* thus anticipating, from his comparative studies, the conclusions of Bigsby.

The crystalline rocks of Anglesea and the adjacent part of Caernarvon, which have been described and mapped by the British Geological Survey as altered lowest Cambrian, are directly overlaid by strata of the Llandeilo and Bala divisions, corresponding to the Trenton and Hudson River formations. If we consult Ramsay's report on the region, it will be found that he speaks of them as "probably Cambrian," and states, as a reason for that opinion, that they are connected by certain beds of intermediate lithological characters with strata of undoubted Cambrian age.† These, however, as he admits, present great local variations, and, after carefully scanning the whole of the evidence adduced, I am inclined to see in it nothing more than the existence, in this region, of Cambrian strata made up from the ruins from the great mass of pre-Cambrian schists, which are the crystalline rocks of Anglesea. Such a phenomenon is repeated, in numerous instances, in our North American rocks, and is the true explanation of many supposed examples of passage from crystalline schists to [illegible] talline sediments. The Anglesea rocks are a highly in[illegible]

* Canadian Naturalist, VII. 125.

† Geol. of North Wales, pp. 145, 175.

much contorted series of quartzose, micaceous, chloritic, and epidotic schists, with diorites, and dark-colored chromiferous serpentines, all of which, after a careful examination of them in the collections of the Geological Survey of Great Britain, appear to me identical with the rocks of the Green Mountain, or Huronian series. A similar view of their age is shared by Phillips and by Sedgwick, in opposition to the opinion of the British Survey. The former asserts that the crystalline schists of Anglesea are "below all the Cambrian rocks;"* while Sedgwick expresses the opinion that they are of "a distinct epoch from the other rocks of the district, and evidently older." †

Associated with the fossiliferous Devonian rocks of the Rhine is a series of crystalline schists, similar to those just noticed, seen in the Taunus, the Hundsrück, and the Ardennes. These, in opposition to Dumont, who regarded them as belonging to an older system, are declared by Römer to have resulted from a subsequent alteration of a portion of the Devonian sediments. ‡

Turning now to the Highlands of Scotland, we have a similar series of crystalline schists, presenting all the mineralogical characters of those of Norway and of Anglesea, which, according to Murchison and Giekie, are neither of Cambrian nor pre-Cambrian age, but are younger than the fossiliferous limestones of the western coast (about the horizon of the Levis formation), which seem to pass beneath them. Professor Nicol, on the contrary, maintains that this apparent superposition is due to uplifts, and that these crystalline schists are really older than either Cambrian or Silurian, both of which appear to the west of them as uncrystalline sediments, resting on the Laurentian. He does not, however, confound these crystalline schists of the Scottish Highlands with the Laurentian, from which they differ mineralogically, but regards them as a distinct series.§ In the presence of the differences of opinion which have been shown in this controversy, we may be permitted to ask whether, in such a case, stratigraphical evidence alone is to be relied upon. Repeated examples have shown that the most skilful stratigraphists may be misled in studying the structure of a disturbed region, where there are no organic remains

* Manual of Geology (1855), 89.

† Geol. Journal for 1845, 449.

‡ Naumann, Geognosie, 2d edition, II. 383.

§ Quar. Jour. Geol. Soc.; Murchison, XV. 353; Giekie, XVII. 171; Nicol, XVII. 58, XVIII. 443.

to guide them, or where unexpected faults and overslides may deceive even the most sagacious. I am convinced that, in the study of the crystalline schists, the persistence of certain mineral characters must be relied upon as a guide, and that the language used by Delesse, in 1847, will be found susceptible of a wide application to crystalline strata. "Rocks of the same age have most generally the same chemical and mineralogical composition, and, reciprocally, rocks having the same chemical composition and the same minerals, associated in the same manner, are of the same age."*

In this connection the testimony of Professor James Hall is to the point. Speaking of the crystalline schists of the White Mountain series, he says: —

"Every observing student of one or two years' experience in the collection of minerals in the New England States knows well that he may trace a mica-schist of peculiar, but varying character, from Connecticut, through central Massachusetts, and thence into Vermont and New Hampshire, by the presence of staurolite and some other associated minerals, which mark with the same unerring certainty the geological relations of the rock, as the presence of *Pentamerus oblongus*, *P. galeatus*, *Spirifer Niagarensis*, or *S. macropleura*, and their respectively associated fossils do the relations of the several rocks in which these occur."†

I am convinced that these crystalline schists of Germany, Anglesea, and the Scotch Highlands, will be found, like those of Norway, to belong to a period anterior to the deposition of the Cambrian sediments, and will correspond with the newer gneissic series of our Appalachian region. There exists in the Highlands of Scotland a great volume of fine-grained, thin-bedded mica-schists, with andalusite, staurolite, and cyanite, which are met with in Argyleshire, Aberdeenshire, Banffshire, and the Shetland Isles. Rocks, regarded by Harkness as identical with these of the Scottish Highlands, also occur in Donegal and Mayo, in Ireland. Through the kindness of the Rev. Prof. Haughton, of Trinity College, and Mr. Robert H. Scott, then of Dublin, I received some years since a large collection of the crystalline rocks of Donegal, which I am thus enabled to compare with those of North America, and to assert the existence, in the north-west of Ireland, of our second and third series of crystalline schists. The Green Mountain rocks

* Bull. Soc. Geol. de Fr. (2), IV. 786.

† Paleontology of New York, Vol. III., Introduction, p. 93.

are there exactly represented by the dark-colored chromiferous serpentines of Aghadoey, and the steatite, crystalline talc, and actinolite of Crohy Head; while the mica-schist of Loch Derg, with white quartz, blue cyanite, staurolite, and garnet, all united in the same fragment, cannot be distinguished from specimens found at Cavendish, Vermont, and Windham, Maine. The fine-grained andalusite-schists of Clooney Lough are exactly like those from Mount Washington; while the granitoid mica-slates from several other localities in Donegal are not less clearly of the type of the White Mountain series. Similar micaceous schists, with Andalusite (chiastolite), occur on Skiddaw, in Cumberland, England, the relations of which have been clearly defined by Sedgwick, who groups the rocks of Skiddaw into four divisions. The lowest of these, succeeding the granite, is a series of crystalline rocks, not described lithologically, with mineral veins, "having some resemblance to the rocks of Cornwall," and including, towards the summit, "chiastolite schists and chiastolite rocks." These are followed, in ascending order, by two great series of slates and grits, succeeded by a fourth division of schists, sometimes carbonaceous, holding, in parts, fucoids and graptolites, which are apparently overlaid discordantly by sundry trappean conglomerates and chloritic slates.* The graptolites of the Skiddaw slates are found to be identical with those of the Levis formation,† and it is worthy of notice that, although Sedgwick places the mica-schists with andalusite (chiastolite) so far below the graptolitic beds, he elsewhere, in comparing the rocks of North Wales and Cumberland, states that the chloritic and micaceous rocks of Anglesea and Caernarvon are not represented in Cumberland, being distinct from the other rocks of North Wales, and much older.‡

In Victoria, Australia, the position of the chiastolite schists, according to Selwyn, is beneath the graptolitic slates. Boblaye, it is true, asserted, in 1838, that the chiastolite schists of Les Salles, near Pontivy, in Brittany, include *Orthis* and *Calymene*,§ but when we remember that even experienced observers, in the White Mountains, for a time, mistook for remains of crustacea and brachiopods

* Synopsis of British Paleozoic Rocks, p. lxxxiv., being an introduction to McCoy's Brit. Pal. Fossils (1855).

† Harkness and Salter, Quar. Jour. Geol. Soc., xix. 135.

‡ Geol. Journal (1845), IV. 583.

Bull. Soc. Geol. de Fr., X. 227.

certain obscure forms, which they afterwards found not to be organic, and that Dana, in this connection, has called attention to the deceptive resemblance to fossils presented by some imperfectly developed chiastolite crystals in the same region,* we may well require a verification of Boblaye's observation, especially since we find that more recently D'Archiac and Dalimier agree with De Beaumont and Dufrenoy in placing the chiastolite schists of Brittany at the very base of the transition sediments, marking the summit of the crystalline schists.†

With regard to the crystalline schists of Lakes Huron and Superior, to which the name of the Huronian system has been given, the observations of all who have studied the region concur in placing them unconformably beneath the sediments which are supposed to represent the base of the New York system; while, on the other hand, they rest unconformably on the Laurentian gneiss, fragments of which are included in the Huronian conglomerates. The gneissic series of the Green Mountains had, however, as we have seen, been, since 1841, regarded by the brothers Rogers, Mather, Hall, Hitchcock, Adams, Logan, myself, and others, as of Silurian age. Eaton and Emmons had alone claimed for it a pre-Cambrian age, until, in 1862, Macfarlane ventured to unite it with the Huronian system, and to identify both with the crystalline schists of a similar age in Norway. Later observations in Michigan justify still farther this comparison, for not only the more schistose beds of the Green Mountain series, but even the mica-schists of the third or White Mountain series, with staurolite and garnet, are represented in Michigan, as appears by the recent collections of Major Brooks, of the Geological Survey of Michigan, kindly placed in my hands for examination. He informs me that these latter schists are the highest of the crystalline strata in the northern peninsula.

To the north of Lake Superior, as I have already shown elsewhere, the schists of this third series, which, as early as 1861, I compared to those of the Appalachians, are widely spread; while, in Hastings County, forty miles north of Lake Ontario, rocks having the mineralogical and lithological characters both of the second and third series are found resting on the first or Laurentian, the three apparently unconformable, and all in turn overlaid by horizontal Trenton limestone.‡

* Amer. Jour. Sci., II., i. 415, v. 116.
† Bull. Soc. Geol. de Fr., II., xviii. 664.
‡ Amer. Jour. Sci., II., xxxi. 395, and l. 85.

We have shown that, in Pennsylvania, while some of these schists of the second and third series were regarded as altered primal rocks by H. D. Rogers, others, lithologically similar, were referred by him to the older so-called azoic series, which we believe to be their true position. Professor W. B. Rogers has lately informed me that in Virginia the gneissic series having the characters of the Green Mountain rocks is clearly overlaid unconformably by the lowest primal paleozoic strata of the region. Coming northward, the uncrystalline argillites and sandstones, holding Paradoxides, at Braintree, Massachusetts,* and St. John, New Brunswick, overlie unconformably crystalline schists of the second series, and in the latter region, in one locality, rocks which are by Bailey and Matthew regarded of Laurentian age. In Newfoundland, in like manner, a great series of crystalline schists, in which Mr. Murray recognizes the Huronian system, as first studied and described by him in the west, is unconformably overlaid by a group of sandstones, limestones, and slates, holding Paradoxides. The peculiar gneisses and mica-schists of the White Mountain series appear to be developed to a great extent in Newfoundland, which has led me to propose for them the name of the Terranovan system.†

From the part which the ruins of these rocks play in the production of succeeding sediments, it is not always easy to define the limits between the ancient mica-schists and the Cambrian strata in these north-eastern regions. It is not impossible that the two may graduate into each other, as some have supposed, in Newfoundland and Nova Scotia; but, until farther light is thrown upon the subject, I am disposed to regard the relation between the two as one of derivation rather than of passage.

We have already alluded to the history of the rocks of the White Mountains, formerly looked upon as primary, and, by Jackson, described as an old granitic and gneissic axis uplifting the more recent Green Mountain rocks. Their manifest differences from the more ancient gneiss of the Adirondacks, and their apparent superposition to the Green Mountain series, then regarded by the Messrs. Rogers as belonging to the Champlain division, led them, in 1846, to look upon the White Mountains as altered strata belonging to the Levant division of their classification, corresponding to the Oneida, Medina, and Clinton of the New York system.

* Hunt, Proc. Bost. Nat. Hist. Soc., Oct. 19, 1870.

† Amer. Jour. Sci., II., l. 87.

In 1848 Sir William Logan came to a somewhat similar conclusion. Accepting, as we have seen, the view of Emmons that the strata about Quebec included a portion of the Levant division, and regarding the Green Mountain gneisses as the equivalents of these, he was induced to place the White Mountain rocks still higher in the geological series than the Messrs. Rogers had done, and expressed his belief that they might be the altered representatives of the New York system, from the base of the Lower Helderberg to the top of the Chemung; in other words, that they were not Middle Silurian, but Upper Silurian and Devonian. This view, adopted and enforced by me,* was farther supported by Lesley in 1860, and has been generally accepted up to this time. In 1870, however, I ventured to question it, and in a published letter, addressed to Professor Dana, concluded, from a great number of facts, that there exists a system of crystalline schists, distinct from, and newer than, the Laurentian and Huronian, to which I gave the provisional name of Terranovan, constituting the third or White Mountain series, which appears not only throughout the Appalachians, but westward, to the north of Lake Ontario, and around and beyond Lake Superior.† Although I have, in common with most other American geologists, maintained that the crystalline rocks of the Green Mountain and White Mountain series are altered paleozoic sediments, I find, on a careful examination of the evidence, no satisfactory proof of such an age and origin, but an array of facts which appear to me incompatible with the hitherto received view, and lead me to conclude that the whole of our crystalline schists of eastern North America are not only pre-Silurian but pre-Cambrian in age.

In what precedes, I have endeavored to discuss briefly and impartially some of the points in the history of the older rocks, and of the views which during the past thirty years have been entertained as to their age and geological relations both in America and in Europe. I have said some things which will provoke criticism, and, at the same time, I trust, lead to farther study of these rocks, a correct knowledge of which lies at the basis of geological science.

I cannot, however, conclude this part of my subject without

* Geol. Survey of Canada, Report 1847–48, p. 58; also Amer. Jour. Sci., II., ix. 19.

† Amer. Jour. Sci., II., l. 83.

referring to the views put forth in 1869 by Professor Hermann Credner, of Leipzig, in an essay on the Eozoic or pre-Silurian formations of North America.* With Macfarlane, he refers to the Huronian the gneissic series of the Green Mountains, but includes with it, as part of the Huronian system, the so-called Lower Taconic rocks of Vermont, "with remains of annelids and crinoids." Credner thus falls into the very error against which Emmons warned American geologists, namely, the confounding in one system the ancient crystalline schists with the newer fossiliferous sediments. Resting unconformably on these, he places, first, the Upper Taconic, corresponding, according to him, to a part of the Quebec group, and, second, the Potsdam sandstone. In this he has copied, for the most part, Marcou, who, however, groups the whole of these various divisions in the Taconic system, while Credner, rejecting the name, unites a portion of the Taconic of Emmons with the Huronian system, and refers the other portion, together with the Potsdam, to the Silurian. These same views are set forth, in a more recent paper, by the same author, on the Alleghany system, which is accompanied with sections and a geologically colored map.† In this, not content with including in the Huronian both the fossiliferous strata of the Levis formation and the crystalline schists of the Green Mountains, he refers the gneisses and mica-schists of the White Mountains to the same system; while the broad area of similar rocks, from their base to the sea at Portland, is regarded as Laurentian. This, on Credner's map, is also made to include, with the exception of the White Mountains themselves, all the rocks of the third or White Mountain series, which cover so large a part of New England. Those who have followed the historical sketch already given can see how widely these notions of Credner differ from those of Emmons, and from all other American geologists, and how much they are at variance with the present state of our knowledge. It is much to be regretted that so good a geologist and lithologist should, from a too superficial study, have fallen into these errors, which can only retard the progress of comparative geognosy, for which he has done so much. In England, again, Credner confounds the Cambrian and Huronian, referring to the latter system the whole

* Die Gliederung der Eozoischen Formationsgruppe, u. s. w., p. 58. Halle, 1869.

† Petermann's Geographische Mittheilungen. 2 Heft, 1871.

of the Longmynd rocks, with their characteristic Cambrian fauna, a view which is supported only by the conjectured Cambrian age of the crystalline schists of Anglesea, which are probably pre-Cambrian, and veritably Huronian, like the Urschiefer of Scandinavia; which Credner correctly refers to the latter system, as Macfarlane and Bigsby had done before him. He, moreover, recognizes in the similar crystalline schists of Scotland, the Urals, and various parts of Germany, including those of Bavaria and Bohemia, a newer system, overlying the primary or Laurentian gneiss, and corresponding to the Huronian or Green Mountain series of North America, while he suggests a correspondence with similar rocks in Japan, Bengal, and Brazil. In a collection of rocks brought from the latter country by Professor C. F. Hartt, I have found, as elsewhere stated,* what appear to be representatives of the three types of crystalline schists which have been distinguished in eastern North America.

It will be noticed that I have not, in the preceding pages, referred to the Labradorian (Upper Laurentian) system, which is characterized by a great predominance of norites and hyperites. Although occupying a considerable area in the Adirondack region, it is not certainly known in the Appalachian range, and was, therefore, omitted in the discussion. In addition to the facts given by me in 1869,† it may be added that the observations of Mr. Richardson, during that season, on the north side of the Gulf of St. Lawrence, confirm the previous conclusions, and show that the rocks of the Labradorian (or rather Norian) system there repose transgressively, and often at comparatively moderate angles, on the nearly vertical Laurentian gneisses.‡ We may, I think, in the present state of our knowledge, regard these norites or Norian rocks as portions of a pre-Huronian system.

II. — The Origin of Crystalline Rocks.

We now approach the second part of our subject, namely, the genesis of the crystalline schists, whose history we have just discussed. The origin of the mineral silicates, which make up a great portion of the crystalline rocks of the earth's surface, is a ques-

* The Nation, Dec. 1, 1870, and Hartt's Geology of Brazil, p. 550.

† On Norites, &c., Amer. Jour. Sci., II., xlviii. 180.

‡ Geol. Survey of Canada, Report 1866–69, p. 306.

tion of much geological interest, which has been to a great degree overlooked. The gneisses, mica-schists, and argillites of various geological periods do not differ very greatly in chemical constitution from modern mechanical sediments, and are now very generally regarded as resulting from a molecular rearrangement of similar sediments formed in earlier times by the disintegration of previously existing rocks not very unlike them in composition; the oldest known formations being still composed of crystalline stratified deposits presumed to be of sedimentary origin. Before these the imagination conceives yet earlier rocks, until we reach the surface of unstratified material which the globe may be supposed to have presented before water had begun its work. It is not, however, my present plan to consider this far-off beginning of sedimentary rocks, which I have elsewhere discussed.*

Apart from the clay and sandrocks just referred to, whose composition may be said to be essentially quartz and aluminous silicates, chiefly in the forms of feldspars and micas, or the results of their partial decomposition and disintegration, there is another class of crystalline silicated rocks, which, though far less important in bulk than the last, is of great and varied interest to the lithologist, the mineralogist, the geologist, and chemist. The rocks of this second class may be defined as consisting in great part of the silicates of the protoxyd bases, lime, magnesia, and ferrous oxyd, either alone or in combination with silicates of alumina and alkalies. They include the following as their chief constituent mineral species: pyroxene, hornblende, olivine, serpentine, talc, chlorite, epidote, garnet, and triclinic feldspars, such as labradorite. The great types of this second class are not less well defined than the first, and consist of pyroxenic and hornblendic rocks, passing into diorites, diabases, ophiolites, and talcose, chloritic, and epidotic rocks. Intermediate varieties, resulting from the association of the minerals of this class with those of the first, and also with the materials of non-silicated rocks, such as limestones and dolomites, show an occasional blending of the conditions under which these various types of rocks were formed.

The distinctions just drawn between the two great divisions of silicated rocks, are not confined to stratified deposits, but are equally well marked in eruptive and unstratified masses, among which the first type is represented by trachytes and granites, and the second

* Amer. Jour. Science, II., l. 25.

by dolerites and diorites. This fundamental difference between acid and basic rocks, as the two classes are called, finds its expression in the theories of Phillips, Durocher, and Bunsen, who have deduced all silicated rocks from two supposed layers of molten matter within the earth's crust, consisting respectively of acid and basic mixtures; the trachytic and pyroxenic magmas of Bunsen. From these, by a process of partial crystallization and eliquation, or by commingling in various proportions, those eruptive rocks which depart more or less from the normal types are supposed by the theorists of this school to be generated.* The doctrine that these eruptive rocks are not derived directly from a hitherto uncongealed nucleus, but are softened and crystallized sediments, in fact, that the whole of the rocks at present known to us have at one time been aqueous deposits, has, however, found its advocates. In support of this view I have endeavored to show that the natural result of forces constantly in operation tends to resolve the various igneous rocks into two classes of sediments, in which the two types are, to a great extent, preserved. The mechanical and chemical agencies which transform the crystalline rocks into sediments, separate these more or less completely into coarse, sandy, permeable beds on the one hand, and fine clayey impervious muds on the other. The action of infiltrating atmospheric waters on the first and more silicious strata removes from them lime, magnesia, iron-oxyd, and soda, leaving behind silica, alumina, and potash, — the elements of granitic, gneissic, and trachytic rocks. The finer and more aluminous sediments, including the ruins of the soft and easily abraded silicates of the pyroxene group, resisting the penetration of the water, will, on the contrary, retain their alkalies, lime, magnesia, and iron, and thus will have the composition of the more basic rocks.†

A little consideration will, however, show that this process, although doubtless a true cause of differences in the composition of sedimentary rocks, is not the only one, and is inadequate to explain the production of many of the varieties of stratified silicated rocks. Such are serpentine, steatite, hornblende, diallage, chlorite, pinite, and labradorite, all of which mineral species form rock-masses by themselves, frequently almost without admixture. No geological student will now question that all of these rocks occur as

* Hunt on Some Points of Chemical Geology, Quar. Jour. Geol. Soc., XV. 489.

† Quar. Jour. Geol. Soc., xv. 489; also, Amer. Jour. Sci., II., xxx. 133.

members of stratified formations. Moreover, the manner in which serpentines are found interstratified with steatite, chlorite, argillite, diorite, hornblende, and feldspar rocks, and these, in their turn, with quartzites and orthoclase rocks, is such as to forbid the notion that these various materials have been deposited, with their present composition, as mechanical sediments from the ruins of pre-existing rocks; a hypothesis as untenable as that ancient one which supposed them to be the direct results of plutonic action.

There are, however, two other hypotheses which have been proposed to explain the origin of these various silicated rocks, and especially of the less abundant, and, as it were, exceptional species just mentioned. The first of these supposes that the minerals of which they are composed have resulted from an alteration of previously existing minerals, often very unlike in composition to the present, by the taking away of certain elements and the addition of certain others. This is the theory of metamorphism by pseudomorphic changes, as they are called, and is the one taught by the now reigning school of chemical geologists, of which the learned and laborious Bischof, whose recent death science deplores, may be regarded as the great exponent. The second hypothesis supposes that the elements of these various rocks were originally deposited, as, for the most part, chemically formed sediments or precipitates; and that the subsequent changes have been simply molecular, or, at most, confined in certain cases to reactions between the mingled elements of the sediments, with the elimination of water and carbonic acid. It is proposed to consider briefly these two opposite theories, which seek to explain the origin of the rocks in question respectively by pseudomorphic changes in pre-existing crystalline rocks, and by the crystallization of aqueous sediments, for the most part chemically formed precipitates.

Mineral pseudomorphism, that is to say, the assumption by one mineral substance of the crystalline form of another, may arise in several ways. First of these is the filling up of a mould left by the solution or decomposition of an embedded crystal, a process which sometimes takes place in mineral veins, where the processes of solution and deposition can be freely carried on. Allied to this is the mineralization of organic remains, where carbonate of lime or silica, for example, fills the pores of wood. When subsequent decay removes the woody tissue, the vacant spaces may,

in their turn, be filled by the same or another species.* In the second place, we may consider pseudomorphs from alteration, which are the result of a gradual change in the composition of a mineral species. This process is exemplified in the conversion of feldspar into kaolin by the loss of its alkali and a portion of silica, and the fixation of water, or in the change of chalybite into limonite by the loss of carbonic acid and the absorption of water and oxygen.

The doctrine of pseudomorphism by alteration, as taught by Gustaf Rose, Haidinger, Blum, Volger, Rammelsberg, Dana, Bischof, and many others, leads them, however, to admit still greater and more remarkable changes than these, and to maintain the possibility of converting almost any silicate into any other. Thus, by referring to the pages of Bischof's "Lehrbuch der Geognosie," it will be found that serpentine is said to exist as a pseudomorph after augite, hornblende, olivine, chondrodite, garnet, mica, and probably also after labradorite, and even orthoclase. Serpentine rock, or ophiolite, is supposed to have resulted, in different cases, from the alteration of hornblende-rock, diorite, granulite, and even granite. Not only silicates of protoxyds and aluminous silicates are conceived to be capable of this transformation, but probably also quartz itself; at least, Blum asserts that meerschaum, a closely related silicate of magnesia, which sometimes accompanies serpentine, results from the alteration of flint; while, according to Rose, serpentine may even be produced from dolomite, which we are told is itself produced by the alteration of limestone. But this is not all, — feldspar may replace carbonate of lime, and carbonate of lime feldspar; so that, according to Volger, some gneissoid limestones are probably formed from gneiss by the substitution of calcite for orthoclase. In this way, we are led from gneiss or granite to limestone, from limestone to dolomite, and from dolomite to serpentine, or, more directly, from granite, granulite, or diorite, to serpentine at once, without passing through the intermediate stages of limestone and dolomite, till we are ready to exclaim, in the words of Goethe: —

> "Mich ängstigt das Verfängliche
> Im widrigen Geschwätz,
> Wo Nichts verharret, Alles flieht,
> Wo schon verschwunden was man sieht," †

* Hunt on the Silicification of Fossils, Canadian Naturalist, new series, I. 46.

† Chinesisch-Deutsche Jahres und Tages Zeiten, xi.

gests that itself is a product of the alteration of orthoclase. In like manner the mica, which in some cases coats tourmaline, and in others fills hollow prisms of this mineral, is supposed to result from a subsequent alteration of crystallized tourmaline. So in the case of shells of leucite filled with feldspar, or of garnet enclosing epidote, or chlorite, or quartz, a similar transformation of the interior is supposed to have been mysteriously effected, while the external portion of the crystal remains intact. Again, the aggregates of tinstone, quartz, and orthoclase, having the form of the latter, are, by Bischof and his school, looked upon as results of a partial alteration of previously formed orthoclase crystals. It needed only to extend this view to the crystals of calcite enclosing sand-grains, and regard these as the result of a partial alteration of the carbonate of lime. There is absolutely no proof that these hard crystalline substances can undergo the changes supposed, or can be absorbed and modified like the tissues of a living organism. It may, moreover, be confidently affirmed that the obvious facts of envelopment are adequate to explain all the cases of association upon which this hypothesis of pseudomorphism by alteration has been based. Why the change should extend to some parts of a crystal and not to others; why, in some cases, the exterior of the crystal is altered, while in others the centre alone is removed and replaced by a different material, are questions which the advocates of this fanciful hypothesis have not explained. As taught by Blum and Bischof, however, these views of the alteration of mineral species have not only been generally accepted, but have formed the basis of the generally received theory of rock-metamorphism.

Protests against the views of this school have, however, not been wanting. Scheerer, in 1846, in his researches in Polymeric Isomorphism,* attempted to show that iolite and aspasiolite, a hydrous species which had been looked upon as resulting from its alteration, were isomorphus species crystallizing together, and, in like manner, that the association of olivine and serpentine in the same crystal, at Snarum in Norway, was a case of envelopment of two isomorphous species. In both of these instances he maintained the existence of isomorphous relations between silicates in which 3HO replaced MgO. He hence rejected the view of Gustaf Rose, that these serpentine crystals were results of the alteration of

* Pogg. Annal., lxviii. 319

olivine, and supported his own by reasons drawn from the conditions in which the crystals occur. In 1853 I took up this question, and endeavored to show that these cases of isomorphism, described by Scheerer, entered into a more general law of isomorphism pointed out by me among homologous compounds differing in their formulas by nM_2O_2 (M = hydrogen or a metal). I insisted, moreover, on its bearing upon the received views of the alteration of minerals, and remarked, "The generally admitted notions of pseudomorphism seem to have originated in a too exclusive plutonism, and require such varied hypotheses to explain the different cases, that we are led to seek for some more simple explanation, and to find it, in many instances, in the association and crystallizing together of homologous and isomorphous species." * Subsequently, in 1860, I combated the view of Bischof, adopted by Dana, that "regional metamorphism is pseudomorphism on a grand scale," in the following terms: —

> "The ingenious speculations of Bischof and others, on the possible alteration of mineral species by the action of various saline and alkaline solutions, may pass for what they are worth, although we are satisfied that by far the greater part of the so-called cases of pseudomorphism in silicates are purely imaginary, and, when real, are but local and accidental phenomena. Bischof's notion of the pseudomorphism of silicates like feldspars and pyroxenes, presupposes the existence of crystalline rocks, whose generation this neptunist never attempts to explain, but takes his starting-point from a plutonic basis."

I then asserted that the problem to be solved in regional metamorphism is the conversion of sedimentary strata, "derived by chemical and mechanical agencies from the ocean-waters, and preexisting crystalline rocks, into aggregations of crystalline silicates. These metamorphic rocks, once formed, are liable to alteration only by local and superficial agencies, and are not, like the tissues of a living organism, subject to incessant transformations, the pseudomorphism of Bischof." †

I had not, at that time, seen the essay, by Delesse, on Pseudomorphs, already referred to, published in 1859, in which he maintained views similar to those set forth by me in 1853 and 1860, declaring that much of what had been regarded as pseudomorphism had no other basis than the observed associations of minerals, and

* Amer. Jour. Sci., II., xvi. 218.
† Ibid., II., xxx. 135.

that often "the so-called metamorphism finds its natural explanation in envelopment." These views he ably and ingeniously defended by a careful discussion of the whole range of facts belonging to the history of the subject.

My own expression of opinion on this question, in 1853, had been privately criticised, and I had been charged with a want of comprehension of the question. It was, therefore, with no small pleasure, that I not only saw my views so ably supported by Delesse, but read the language of Carl Friedrich Naumann, who in 1861 wrote to Delesse as follows, referring to his essay just noticed:—

"You have rendered a veritable service to science in restricting pseudomorphs to their true limits, and separating what had been erroneously united to them. As you have remarked, envelopments have, for the most part, nothing in common with pseudomorphs, and it is inconceivable that they have been united by so many mineralogists and geologists. It appears to me, moreover, that they commit an analogous error, when they regard gneisses, amphibolites, &c., as being, all of them, the results of metamorphic epigenesis, and not original rocks. It is precisely because pseudomorphism has been so often confounded with metamorphism that this error has found acceptance. I only admit a pseudomorph where there is some crystal, the form of which has been preserved. There are very many metamorphic substances which are, in no sense of the word, pseudomorphs. Had the name of *crystalloid* been chosen, instead of pseudomorph, this confusion would certainly have never found its way into the science. I think, with you, that the envelopment of two minerals is most generally explained by a *contemporaneous* and *original* crystallization. Secondary envelopments, however, exist, and such may be called pseudomorphs or crystalloids, if they reproduce exactly the form of the crystal enveloped, whether this last still remains, or has entirely disappeared." *

It is unnecessary to remark that the view of Delesse and Naumann, viz., that the so-called cases of pseudomorphism, on which the theory of metamorphism by alteration has been built, are, for the most part, examples of association and envelopment, and the result of a contemporaneous and original crystallization, — is identical with the view suggested by Scheerer, and generalized by myself long before, when, in 1853, I sought to explain the phenomena in question by "the association and crystallizing together of homologous and isomorphous species."

Later, in 1862, I wrote as follows:—

* Bull. Soc. Geol. de France, II., xviii. 678.

"Pseudomorphism, which is the change of one mineral species into another, by the introduction or the elimination of some element or elements, presupposes metamorphism (*i.e.*, metamorphic or crystalline rocks), since only definite mineral species can be the subjects of this process. To confound metamorphism with pseudomorphism, as Bischof and others after him have done, is therefore an error. It may be farther remarked, that, although certain pseudomorphic changes may take place in some mineral species, in veins, and near the surface, the alteration of great masses of silicated rocks by such a process is, as yet, an unproved hypothesis." *

Thus this unproved theory of pseudomorphism, as taught by Bischof, does not, even if admitted to its fullest extent, advance us a single step towards a solution of the problem of the origin of the various silicates, which, singly or intermingled, make up beds in the crystalline schists. Granting, for the sake of argument, that serpentine results from the alteration of olivine or labradorite, and steatite or chlorite from hornblende, the origin of these anhydrous silicates, which are the subjects of the supposed change, is still unaccounted for. The explanation of this short-sightedness is not far to seek; as already remarked, Bischof, although a professed neptunist, starts from a plutonic basis. When the epigenic origin of serpentine and its related rocks was first taught, these were regarded as eruptive and unstratified, and it was easy to imagine intruded masses of dioritic and feldspathic rocks, which had become the subjects of alteration. As, however, the progress of careful investigation in the field has shown the stratified character of these serpentines, diallage-rocks, steatites, &c., and their intercalation among limestones, argillites, quartzites, gneisses, and mica-schists, and even among feldspathic and hornblendic strata, we are forced to reject, with Naumann, the notion of their epigenic derivation, and to regard them as original rocks.

This view brings us face to face with the problem of metamorphism as defined by me in 1860† (*ante*, page 43). We must either admit that these crystalline schists were created as we find them, or suppose that they were once sands, clays, marls, &c.; in a word, sediments of chemical and mechanical origin, which, by a subsequent process, have been consolidated and crystallized.

* Descriptive Catalogue, Crystalline Rocks of Canada, p. 80, London Exhibition, 1862; also, Dublin Quar. Journal, July, 1863, and Amer. Jour. Sci., II., xxxvi. 218.

† Amer. Jour. Sci., II., xxx. 185.

Whence, then, come these silicates of magnesia, lime, and iron, which are the sources of serpentine, hornblende, steatite, chlorite, &c.? This is the question which I proposed in that same year, when, after discussing the results of my examinations of the tertiary rocks near Paris, containing layers of a hydrous silicate of magnesia, related to talc in composition, among unaltered limestones and clays, I remarked that it is evident "such silicates may be formed in basins at the earth's surface, by reactions between magnesian solutions and dissolved silica;" and, after some farther discussion, said "farther inquiries in this direction may show to what extent certain rocks composed of calcareous and magnesian silicates may be directly formed in the moist way."* Subsequently, in a paper on "The Origin of some Magnesian and Aluminous Rocks," printed in the "Canadian Naturalist" for June, 1860,† I repeated these considerations, referring to the well-known fact that silicates of lime, magnesia and iron-oxyd are deposited during the evaporation of natural waters, including those of alkaline springs and of the Ottawa River. Having described the mode of occurrence of the magnesian silicate, sepiolite, in the Paris basin, and the related quincite, containing some iron-oxyd and disseminated in limestone, I suggested that while steatite has been derived from a compound like sepiolite, the source of serpentine was to be sought in another silicate richer in magnesia; and, moreover, that chlorite, unless the result of a subsequent reaction between clay and carbonate of magnesia, was directly formed by a process analogous to that which (according to Scheerer) has, in recent times, caused the deposition, from waters, of neolite a hydrous alumino-magnesian silicate approaching to chlorite in composition,‡ "the type of a reaction which formerly generated beds of chlorite in the same way as those of sepiolite or talc." Delesse, subsequently, in 1861, in his essay on Rock-Metamorphism, insisted upon the sepiolites, or so-called magnesian marls, as probably the source of steatite, and suggested the derivation of serpentine, chlorite, and other related minerals of the crystalline schists, from deposits approaching these marls in composition.§ He recalled, also, the

* Amer. Jour. Sci., II., xxix. 284; also II., xl. 49.
† Ibid., II., xxxii. 286.
‡ Pogg. Annal, lxxi. 288.
§ Etudes sur le Metamorphisme, quarto, p. 91. Paris, 1861.

occurrence of chromic oxyd, a frequent accompaniment of these magnesian minerals, in the hydrated iron ores of the same geological horizon with the magnesian marls in France. Delesse did not, however, attempt to account for the origin of these deposits of magnesian marls, in explanation of which I afterwards verified Bischof's observations on the sparing solubility of silicate of magnesia, and showed that silicate of soda, or even artificial hydrated silicate of lime, when added to waters containing magnesian chlorid or sulphate, gives rise, by double decomposition, to a very insoluble magnesian silicate.*

To explain the generation of silicates like labradorite, scapolite, garnet, and saussurite, I suggested that double aluminous silicates allied to the zeolites might have been formed, and subsequently rendered anhydrous. The production of zeolitic minerals observed by Daubrée at Plombières and Luxeuil, by the action of a silicated alkaline water on the masonry of ancient Roman baths, was appealed to by way of illustration. It had there been shown by Daubrée that the elements of the zeolites had been derived in part from the waters, and in part from the mortar, and even the clay of the bricks, which had been attacked, and had entered into combination with the soluble matters of the water to form chabazite. I, however, at the same time pointed out another source of silicated minerals, upon which I had insisted since 1857, viz., the reaction between silicious or argillaceous matters and earthy carbonates in the presence of alkaline solutions. Numerous experiments showed that when solutions of an alkaline carbonate were heated with a mixture of silica and carbonate of magnesia, the alkaline silicate formed acted upon the latter, yielding a silicate of magnesia, and regenerating the alkaline carbonate; which, without entering into permanent combination, was the medium through which the union of the silica and the magnesia was effected. In this way I endeavored to explain the alteration, in the vicinity of a great intrusive mass of dolerite, of a grey Silurian limestone, which contained, besides a little carbonate of magnesia and iron-oxyd, a portion of very silicious matter, consisting apparently of comminuted orthoclase and quartz. In place of this, there had been developed in the limestone, near its contact with the dolerite, an amorphous greenish basic silicate, which had seemingly resulted from the union of the silica and alumina with

* Amer. Jour. Sci., II., xl. 49.

the iron oxyd, the magnesia, and a portion of lime. By the crystallization of the products thus generated it was conceived that minerals like hornblende, garnet, and epidote, might be developed in earthy sediments, and many cases of local alteration explained. Inasmuch as the reaction described required the intervention of alkaline solutions, rocks from which these were excluded would escape change, although the other conditions might not be wanting. The natural associations of minerals, moreover, led me to suggest that alkaline solutions might favor the crystallization of aluminous silicates, and thus convert mechanical sediments into gneisses and mica-schists. The ingenious experiments of Daubrée on the part which solutions of alkaline silicates, at elevated temperatures, may play in the formation of crystallized minerals, such as feldspar and pyroxene, were posterior to my early publications on the subject, and fully justified the importance which, early in 1857, I attributed to the intervention of alkaline silicates in the formation of crystalline silicated minerals.*

While, however, there is good reason to believe that solutions of alkaline silicates or carbonates have been efficient agents in the crystallization and molecular re-arrangement of ancient sediments, and have also played an important part in that local alteration of sedimentary strata, which is often observed in the vicinity of intrusive rocks, it is clear to me that the agency of these solutions is less universal than once supposed by Daubrée and myself, and will not account for the formation of various silicated rocks found among crystalline schists, such as serpentine, hornblende, steatite, and chlorite. When I commenced the study of these crystalline strata I was led, in accordance with the almost universally received opinion of geologists, to regard them as resulting from a subsequent alteration of paleozoic sediments, which according to different authorities, were of Cambrian, Silurian, or Devonian age. Thus in the Appalachian region, as we have already seen, they have, on supposed stratigraphical evidence, been successively placed at the base, at the summit, and in the middle of the Lower Silurian or Champlain division of the New York system. A careful chemical examination among the unaltered paleozoic sediments, which in Canada were looked upon as the stratigraphical equivalents of the bands of magnesian silicates in these crystalline schists, showed

* Proc. Royal Soc, May 7, 1857. Amer. Jour. Sci., II., xxiii. 438, and xxv. 289 and 435.

me, however, no magnesian rocks except certain silicious and ferruginous dolomites. From a consideration of reactions which I had observed to take place in such admixtures in presence of heated alkaline solutions, and from the composition of the basic silicates which I had found to be formed in silicious limestones near their contact with eruptive rocks, I was led to suppose that similar actions, on a grand scale, might transform these silicious dolomites of the unaltered strata into crystalline magnesian silicates.

Farther researches, however, convinced me that this view was inapplicable to the crystalline schists of the Appalachians, since, apart from the geognostical considerations set forth in the previous part of this paper, I found that these same crystalline strata hold beds of quartzose dolomite and magnesian carbonate, associated in such intimate relations with beds of serpentine, diallage, and steatite, as to forbid the notion that these silicates could have been generated by any transformations or chemical rearrangement of mixtures like the accompanying beds of quartzose magnesian carbonates. Hence it was that already, in 1860, as shown above, I announced my conclusion that serpentine, chlorite, and steatite, had been derived from silicates like sepiolite, directly formed in waters at the earth's surface, and that the crystalline schists had resulted from the consolidation of previously formed sediments, partly chemical and partly mechanical in their origin. The latter being chiefly silico-aluminous, took, in part, the forms of gneiss and mica-schists, while from the more argillaceous strata, poorer in alkali, much of the aluminous silicate crystallized as andalusite, staurolite, cyanite, and garnet. These views were reiterated in 1863,* and farther, in 1864, in the following language, as regards the chemically formed sediments: "Steatite, serpentine, pyroxene, hornblende, and in many cases, garnet, epidote, and other silicated minerals are formed by a crystallization and molecular rearrangement of silicates generated by chemical processes in waters at the earth's surface." † Their alteration and crystallization was compared to that of the mechanically formed feldspathic, silicious, and argillaceous sediments just mentioned.

The direct formation of the crystalline schists from an aqueous magma is a notion which belongs to an early period in geological

* Geol. of Canada, pp. 577–581.

† Amer. Jour. Sci., II., xxxvii. 266, and xxxviii. 188.

theory. Delabeche, in 1834,* conceived that they were thrown down as chemical deposits from the waters of the heated ocean, after its reaction on the crust of the cooling globe, and before the appearance of organic life. This view was revived by Daubrée in 1860. Having sought to explain the alteration of paleozoic strata of mechanical origin, by the action of heated waters, he proceeds to discuss the origin of the still more ancient crystalline schists. The first precipitated waters, according to him, acting on the anhydrous silicates of the earth's crust, at a very elevated temperature, and at a great pressure, which he estimated at two hundred and fifty atmospheres, formed a magma, from which, as it cooled, were successively deposited the various strata of the crystalline schists.† This hypothesis, violating, as it does, all the notions which sound theory teaches with regard to the chemistry of a cooling globe, has, moreover, to encounter grave geognostical difficulties. The pre-Silurian crystalline rocks belong to two or more distinct systems of different ages, succeeding each other in discordant stratification. The whole history of these rocks, moreover, shows that their various alternating strata were deposited, not as precipitates from a seething solution, but under conditions of sedimentation very like those of more recent times. In the oldest known of them, the Laurentian system, great limestone formations are interstratified with gneisses, quartzites, and even with conglomerates. All analogy, moreover, leads us to conclude that even at this early period, life existed at the surface of the planet. Great accumulations of iron-oxyd, beds of metallic sulphids, and of graphite, exist in these oldest strata, and we know of no other agency than that of organic matter, capable of generating these products.

Bischof had already arrived at the conclusion, which in the present state of our knowledge seems inevitable, that "all the carbon yet known to occur in a free state, can only be regarded as a product of the decomposition of carbonic acid, and as derived from the vegetable kingdom." He farther adds, "living plants decompose carbonic acid; dead organic matters decompose sulphates, so that, like carbon, sulphur appears to owe its existence in a free state to the organic kingdom."‡ As a decomposition

* Researches in Theoretical Geology, pp. 297–300.

† Etudes et expériences synthétiques sur le Metamorphisme, pp. 119–121.

‡ Bischof, Lehrbuch, 1st ed., II. 95; English ed., I. 252, 344.

(deoxidation) of sulphates is necessary to the production of metallic sulphids, the presence of the latter, not less than that of free sulphur and free carbon, depends on organic bodies; the part which these play in reducing and rendering soluble the peroxyd of iron, and in the production of iron ores, is, moreover, well known. It was, therefore, that, after a careful study of these ancient rocks, I declared in May, 1858, that a great mass of evidence "points to the existence of organic life, even during the Laurentian, or so-called azoic period."*

This prediction was soon verified in the discovery of the *Eozoön Canadense*, of Dawson, the organic character of which is now admitted by all zoölogists and geologists of authority. But with this discovery appeared another fact, which afforded a signal verification of my theory as to the origin and mode of deposition of serpentine and pyroxene. The microscopic and chemical researches of Dawson and myself showed that the calcareous skeleton of this foraminiferal organism was filled with the one or the other of these silicates in such a manner as to make it evident that they had replaced the sarcode of the animal, precisely as glauconite and similar silicates have, from the Silurian times to the present, filled and injected more recent foraminiferal skeletons. I recalled, in connection with this discovery, the observations of Ehrenberg, Mantell, and Bailey, and the more recent ones of Pourtales, to the effect that glauconite or some similar substance occasionally fills the spines of Echini, the cavities of corals and millepores, the canals in the shells of Balanus, and even forms casts of the holes made by burrowing sponges (Clionia) and worms. The significance of these facts was farther illustrated by showing that the so-called glauconites differ considerably in composition, some of them containing more or less alumina or magnesia, and one from the tertiary limestones near Paris being, according to Berthier, a true serpentine.†

These facts in the history of Eozoön, were first made known by me in May, 1864, in the "American Journal of Science," and subsequently more in detail, February, 1865, in a communication to the Geological Society of London.‡ They were speedily verified by Dr. Gümbel, who was then engaged in the study of the ancient

* Amer. Jour. Science, II., xxv. 436.

† Amer. Jour. Sci., II., xl. 360; Report Geol. Survey Canada, 1866, p. 281; and Quar. Geol. Jour., XXI. 71.

‡ Amer. Jour. Sci., II., xxxvii. 431; Quar. Geol. Jour., XXI. 67.

crystalline schists of Bavaria, and soon recognized the existence, in the limestones of the old Hercynian gneiss, of the characteristic *Eozoön Canadense*, injected with silicates in a manner precisely similar to that observed by Dawson and myself.* Later, in 1869, Robert Hoffmann described the results of a minute chemical examination of the Eozoön from Raspenau, in Bohemia, confirming the previous observations in Canada and Bavaria. He showed that the calcareous shell of the Eozoön, examined by him, had been injected by a peculiar silicate, which may be described as related in composition both to glauconite and to chlorite. The masses of Eozoön he found to be enclosed and wrapped around by thin alternating layers of a green magnesian silicate, allied to picrosmine, and a brown non-magnesian mineral, which proved to be a hydrous silicate of alumina, ferrous oxyd, and alkalies, related to fahlunite, or more nearly to jollyte, in composition.†

Still more recently, in the course of the present year, Dr. Dawson detected a mineral insoluble in acids, injecting the pores of crinoidal stems and plates in a paleozoic limestone from New Brunswick, which is made up of organic remains. This silicate, which, in decalcified specimens, shows in a beautiful manner the intimate structure of these ancient crinoids, I have found by analysis to be a hydrous silicate of alumina and ferrous oxyd, with magnesia and alkalies, close related to fahlunite and to jollyte.‡ The microscopic examinations of Dr. Dawson show that this silicate injected the pores of the crinoidal remains and some of the interstices of the associated shell-fragments, before the introduction of the calcite which cements the mass. I have since found a silicate almost identical with this occurring under similar conditions in an Upper Silurian limestone said to be from Llangedoc, in Wales.

Gümbel, meanwhile, in the essay on the Laurentian rocks of Bavaria, in 1866, already referred to, fully recognized the truth of the views which I had put forward, both with regard to mineralogy of Eozoön and to the origin of the crystalline schists. His results are still farther detailed in his *Geognost. Beschreibung des östbayerisches Grenzegebirges*, 1868, p. 833. Credner, moreover, as he tells

* Proc. Royal Bavar. Acad. for 1866, and Can. Naturalist, new series, III. 81.

† Jour. für Prakt. Chem., May, 1869, and Amer. Jour. Sci., III., i. 378.

‡ Amer. Jour. Sci., III., i. 279

us,* had already, from his mineralogical and lithological studies, been led to admit my views as to the original formation of serpentine, pyroxene, and similar silicates (which he cites from my paper of 1865, above referred to†), when he found that Gümbel had arrived at similar conclusions. The views of the latter, as cited by Credner from the work just referred to, are in substance as follows: The crystalline schists, with their interstratified layers, have all the characters of altered sedimentary deposits, and from their mode of occurrence cannot be of igneous origin, nor the result of epigenic action. The originally formed sediments are conceived to have been amorphous, and under moderate heat and pressure to have arranged themselves, and crystallized, generating various mineral species in their midst by a change, which, to distinguish it from metamorphism, by an epigenic process, Gümbel happily designates *diagenesis*.

It is unnecessary to remark, that these views, the conclusions from the recent studies of Gümbel in Germany and Credner in North America, are identical with those put forth by me in 1860.

At the early periods in which the materials of the ancient crystalline schists were accumulated, it cannot be doubted that the chemical processes which generated silicates were much more active than in more recent times. The heat of the earth's crust was probably then far greater than at present, while a high temperature prevailed at comparatively small depths, and thermal waters abounded. A denser atmosphere, charged with carbonic acid gas, must also have contributed to maintain, at the earth's surface, a greater degree of heat, though one not incompatible with the existence of organic life.‡ These conditions must have favored many chemical processes, which, in later times, have nearly ceased to operate. Hence we find that subsequently to the eozoic times, silicated rocks of clearly marked chemical origin are comparatively rare. In the mechanical sediments of later periods certain crystalline minerals may be developed by a process of molecular rearrangement — diagenesis. These are, in the feldspathic and aluminous sediments, orthoclase, muscovite, garnet, staurolite, cyanite, and chiastolite, and, in the more basic sedi-

* Hermann Credner; die Gleiderung der Eozoischen Formationsgruppe Nord Amerikas. Halle, 1869.

† That in the Quar. Geol. Jour., XXI. 67.

‡ Amer. Jour. Sci., II., xxxvi. 396.

ments, hornblendic minerals. It is possible that these latter and similar silicates may sometimes be generated by reactions between silica on the one hand, and carbonates and oxyds on the other, as already pointed out in some cases of local alteration. Such a case may apply to more or less hornblendic gneisses, for example, but no sediments, not of direct chemical origin, are pure enough to have given rise to the great beds of serpentine, pyroxene, steatite, labradorite, &c., which abound in the ancient crystalline schists. Thus, while the materials for producing, by diagenesis, the aluminous silicates just mentioned, are to be met with in the mud and clay-rocks of all ages, the chemically formed silicates, capable of crystallizing into pyroxene, talc, serpentine, &c., have only been formed under special conditions.

The same reasoning which led me to maintain the theory of an original formation of the mineral silicates of the crystalline schists, induced me to question the received notion of the epigenic origin of gypsums and magnesian limestones or dolomites. The interstratification of dolomites and pure limestones, and the enclosure of pebbles of the latter in a paste of crystalline dolomite, are of themselves sufficient to show that in these cases, at least, dolomites have not been formed by the alteration of pure limestones. The first results of a very long series of experiments and inquiries into the history of gypsum were published by me in 1859, and farther researches, reiterating and confirming my previous conclusions, appeared in 1866.* In these two papers, it will, I think, be found that the following facts in the history of dolomite are established, viz.: first, its origin in nature by direct sedimentation, and not by the alteration of non-magnesian limestones; second, its artificial production by the direct union of carbonate of lime and hydrous carbonate of magnesia, at a gentle heat, in the presence of water. As to the sources of the hydrous magnesian carbonate, I have endeavored to show that it is formed from the magnesian chlorid, or sulphate of the sea, or other saline waters, in two ways: first, by the action of the bicarbonate of soda found in many natural waters; this, after converting all soluble lime-salts into insoluble carbonate, forms a comparatively soluble bicarbonate of magnesia, from which a hydrous carbonate slowly separates: second, by the action of bicarbonate of lime in solution, which, with sulphate of magnesia, gives rise to gypsum; this first crystal-

* Amer. Jour. Sci., II., xxxviii. 170, 365; xlii. 49.

lizes out, leaving behind a much more soluble bicarbonate of magnesia, which deposits the hydrous carbonate in its turn. In this way, for the first time, in 1859, the origin of gypsums and their intimate relation with magnesian limestones were explained.

It was, moreover, shown that to the perfect operation of this reaction, an excess of carbonic acid in the solution, during the evaporation, was necessary to prevent the decomposing action of the hydrous monocarbonate of magnesia upon the already formed gypsum. Having found that a prolonged exposure to the air, by permitting the loss of carbonic acid, partially interfered with the process, I was led to repeat the experiment in a confined atmosphere, charged with carbonic acid, but rendered drying by the presence of a layer of dessicated chlorid of calcium. As had been foreseen, the process under these conditions proceeded uninterruptedly, pure gypsum first crystallizing out from the liquid, and subsequently, the hydrous magnesian carbonate.* This experiment is instructive as showing the results which must have attended this process in past ages, when the quantity of carbonic acid in the atmosphere greatly exceeded its present amount.

As regards the hypotheses put forward to explain the supposed dolomitization of previously formed limestones by an epigenic process, I may remark that I repeated very many times, under varying conditions, the often cited experiment of Von Morlot, who claimed to have generated dolomite by the action of sulphate of magnesia on carbonate of lime, in the presence of water at a somewhat elevated temperature under pressure. I showed that what he regarded as dolomite was not such, but an admixture of carbonate of lime, with anhydrous, and sparingly soluble carbonate of magnesia; the conditions in which the carbonate of magnesia is liberated in this reaction, not being favorable to its union with the carbonate of lime to form the double salt which constitutes dolomite. The experiment of Marignac, who thought to form dolomite by substituting a solution of chlorid of magnesium for the sulphate, I found to yield similar results, the greater part of the magnesian carbonate produced passing at once into the insoluble condition, without combining with the excess of carbonate of lime present. The process for the production of the double carbonate described by Ch. Deville, namely, the action of vapors of anhydrous mag-

* Proceedings Royal Institution, May 30, 1867, and Canadian Naturalist, new series, III. 231.

nesian chlorid on heated carbonate of lime, in accordance with Von Buch's strange theory of dolomitization, I have not thought necessary to submit to the test of experiment, since the conditions required are scarcely conceivable in nature. Multiplied geognostical observations show that the notion of the epigenic production of dolomite from limestone is untenable, although its resolution and deposition in veins, cavities, or pores in other rocks is a phenomenon of frequent occurrence.

The dolomites or magnesian limestones may be conveniently considered in two classes: first, those which are found with gypsums at various geological horizons; and second, the more abundant and widely distributed rocks of the same kind, which are not associated with deposits of gypsum. The production of the first class is dependent upon the decomposition of sulphate of magnesia by solutions of bicarbonate of lime, while those of the second class owe their origin to the decomposition of magnesian chlorid or sulphate by solutions of alkaline bicarbonates. In both cases, however, the bicarbonate of magnesia, which the carbonated waters generally contain, contributes a more or less important part to the generation of the magnesian sediments. The carbonated alkaline waters of deep-seated springs often contain, as is well known, besides the bicarbonates of soda, lime, and magnesia, compounds of iron, manganese, and many of the rarer metals in solution, and thus the metalliferous character of many of the dolomites of the second class is explained. The simultaneous occurrence of alkaline silicates in such mineral waters would give rise, as already pointed out, to the production of insoluble silicates of magnesia, and thus the frequent association of such silicates with dolomites and magnesian carbonates in the crystalline schists is explained, as marking portions of one continuous process. The formation of these mineral waters depends upon the decomposition of feldspathic rocks by subterranean or subaërial processes, which were doubtless more active in former ages than in our own. The subsequent action upon magnesian waters of these bicarbonated solutions, whether alkaline or not, is dependent upon climatic conditions, since, in a region where the rainfall is abundant, such waters would find their way down the river-courses to the open sea, where the excess of dissolved sulphate of lime would prevent the deposition of magnesian carbonate. It is in dry and desert regions, with limited lake-basins, that we must seek for the production of magnesian carbonates, and I have argued

from these considerations that much of northeastern America, including the present basins of the upper Mississippi and St. Lawrence, must, during long intervals in the paleozoic period, have had a climate of excessive dryness, and a surface marked by shallow enclosed basins, as is shown by the widely spread magnesian limestones, and the existence of gypsum and rock-salt at more than one geological horizon within that area.* The occurrence of serpentine and diallage at Syracuse, New York, offers a curious example of the local development of crystalline magnesian silicates in Upper Silurian dolomitic strata under conditions which are imperfectly known, and, in the present state of the locality, cannot be studied.†

Since the uncombined and hydrated magnesian mono-carbonate is at once decomposed by sulphate or chlorid of calcium, it follows that the whole of these lime-salts in a sea-basin must be converted into carbonates before the production of carbonated magnesian sediments can begin. The carbonate of lime, formed by the action of carbonates of magnesia and soda, remains at first dissolved as bicarbonate, and is only separated in a solid form, when in excess, or when required for the needs of living plants or animals; which are dependent for their supply of calcareous matter on the bicarbonate of lime produced, in part by the process just described, and in part by the action of carbonic acid on insoluble lime-compounds of the earth's solid crust. So many limestones are made up of calcareous organic remains, that a notion exists among many writers on geology that all limestones are, in some way, of organic origin. At the bottom of this lies the idea of an analogy between the chemical relations of vegetable and animal life. As plants give rise to beds of coal, so animals are supposed to produce limestones. In fact, however, the synthetic process, by which the growing plant, from the elements of water, carbonic acid, and ammonia, generates hydrocarbonaceous and azotized matters, has no analogy with the assimilative process by which the growing animal appropriates alike these organic matters and the carbonate and phosphate of lime. Without the plant, the synthesis of the hydrocarbons would not take place, while, independently of the existence of coral or mollusk, the car-

* Geology of Southwestern Ontario, Amer. Jour. Sci., II., xlvi. 355.

† Geology of the 3d district of New York, 108–110, and Hunt on Ophiolites, Amer. Jour. Sci., II., xxvi. 286.

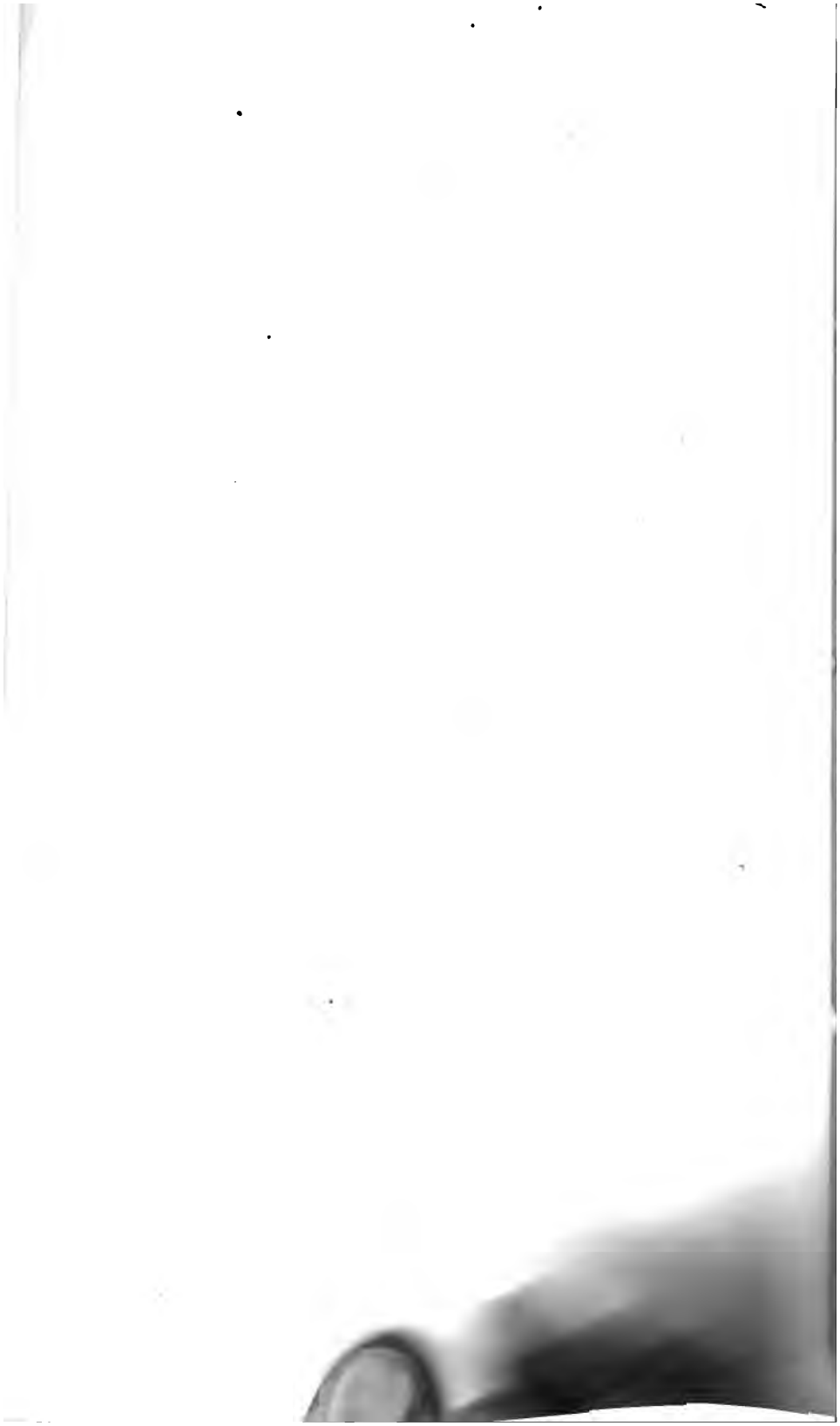
bonate of lime would still be generated by chemical reactions, and would accumulate in the waters until, these being saturated, its excess would be deposited as gypsum or rock-salt are deposited. Hence, in such waters, where, from any causes, life is excluded, accumulations of pure carbonate of lime may be formed. In 1861, I called attention to the white marbles of Vermont, which occur intercalated among impure and fossiliferous beds, as, apparently, examples of such a process.*

It is by a fallacy similar to that which prevails as to the organic origin of limestones, that Daubeny and Murchison were led to appeal to the absence of phosphates from certain old strata as evidence of the absence of organic life at the time of their accumulation.† Phosphates, like silica and iron-oxyd, were doubtless constituents of the primitive earth's crust, and the production of apatite crystals in granitic veins, or in crystalline schists, is a process as independent of life as the formation of crystals of quartz or of hematite. Growing plants, it is true, take up from the soil or the waters dissolved phosphates, which pass into the skeletons of animals, a process which has been active from very remote periods. I showed, in 1854, that the shells of Lingula and Orbicula, both those from the base of the paleozoic rocks, and those of the present time, have (like Conularia and Serpulites) a chemical composition similar to the skeletons of vertebrate animals.‡ The relations of both carbonate and phosphate of lime to organized beings are similar to those of silica, which, like them, is held in watery solution, and by processes independent of life is deposited both in amorphous and crystalline forms, but in certain cases is appropriated by diatoms and sponges, and made to assume organized shapes. In a word, the assimilation of silica, like that of phosphate and carbonate of lime, is a purely secondary and accidental process, and, where life is absent, all of these substances are deposited in mineral and inorganic forms.

I have thus endeavored to sketch, in a concise and rapid manner, the history of the earlier rock-formations of eastern North America, and of our progress in the knowledge of them; while I have, at the same time, dwelt upon some of the geognostical

* Amer. Jour. Sci., II., xxxi. 402.
† Siluria, 4th ed., pp. 28 and 537.
‡ Amer. Jour. Sci., II., xvii. 236.

nd chemical questions which their study suggests. With the ecord of the last thirty years before them, American geologists ıave cause for congratulation that their investigations have been o fruitful in great results. They see, however, at the same time, ıow much yet remains to be done in the study of the Appalachians and of our northeastern coast, before the history of these ancient rock-formations can be satisfactorily written. Meanwhile our adventurous students are directing their labors to the vast regions of western America, where the results which have already been obtained are of profound interest. The progress of these investigations will doubtless lead us to modify many of the views now accepted in science, and cannot fail greatly to enlarge the bound of geological knowledge.



PROCEEDINGS

OF THE

INDIANAPOLIS MEETING, 1871.

COMMUNICATIONS.

A. MATHEMATICS, PHYSICS, AND CHEMISTRY.

I. MATHEMATICS AND ASTRONOMY.

1. An Application of an Exponential Function. By J. E. Hilgard, of Washington, D.C.

In the mint establishments of the United States, it is a rule to deposit a piece, taken at random from each day's work, in a pyx, which is annually sent to the mint in Philadelphia, where it is opened by a Commission appointed each year, for the purpose of carefully assaying and weighing those samples of the national coinage. By such verification and scrutiny the public are assured that the coinage is in conformity with the law, and that operations at the several mints are carried on in a faithful and efficient manner.

The alloys of the metals being made in large quantities, it is to be expected that the proportions should be found very exact, if the work has been done faithfully.

The *aggregate* weight of the number of pieces coined from a given quantity of metal may, in like manner, be required to come very near the prescribed standard. In the weight of *single* pieces, however, some variation must be allowed, in consideration of the unavoidable imperfection of the mechanical processes of rolling and cutting out the coins. This allowance is called the *Tolerance* [redacted] different for pieces of different sizes and values. For the

purpose we have in view here, it is sufficient to state the legal tolerance for the *double eagle*, or twenty-dollar gold piece, the standard weight of which is 516 grains. The law prescribes that no single piece shall be passed that differs more than one-half grain from the standard weight, and that, in an aggregate of 1,000 pieces, the variation from the legal weight shall not exceed three pennyweights, or seventy-two grains. These limits have been prescribed without being made mutually dependent one upon the other, according to any preconceived law, but as safe practical rules, that have been found to work well.

In making the annual assay, however, the Commission is met by the fact that it has not 1,000 pieces of any coinage to deal with; but at most 365, if the work has gone on incessantly. What, then, should be the tolerance on the actual number of pieces submitted?

In an actual case there were 328 double eagles. By the ratio for 1,000 pieces, the tolerance would be twenty-four grains. That for the single pieces, giving 164 grains, is evidently inapplicable, since the law requires a closer agreement for larger amounts. But, by the same consideration, the application of the ratio for 1,000 pieces must be held to be too stringent, especially as it may involve the question of censure.

The law of probabilities, according to which accidental errors accumulate in the ratio of the square root of the number of cases involved, would give, upon the basis of one-half grain for a single piece, a tolerance of sixteen grains for 1,000 pieces. The statute allowing seventy-two grains, it is clear that the law of probabilities has not been held to apply; but an ampler margin has been allowed, which is doubtless proper and necessary, since that law disregards *constant* sources of error, which are likely to obtain in the operations here in question.

We must inquire therefore, What is the law which will represent the two values established by statute without introducing any additional assumption?

Of various functions that might be assumed, we choose the simplest, that, beside fulfilling the stated conditions, also makes the values of both variables simultaneously zero and infinity, conditions necessarily implied. This is a parabolic curve, of the form

$$y = n^x$$

in which the exponent x is for the present our unknown quantity, — whence the title of this paper is derived.

Taking, now, half grains as our unit, we have the tolerance 1 for 1 piece, and 144 for 1,000 pieces. We ask, then, What is the power to which 1,000 must be raised to give 144; or,

$$1000^x = 144?$$

Taking the logarithms, we have $3x = 2.15836$, and hence $x = 0.72$, or we must raise the number of pieces to the power expressed by 0.72, in order to find the tolerance in half grains.

For the case of 328 pieces, we have therefore a tolerance of 64.8 half grains, or 32 grains.

It will be readily seen that, although not a single coin exceeded its tolerance, the average variation need only exceed one-tenth of a grain on one side or the other, to put the aggregate beyond the limit allowed by statute.

In the French mint, the recognized practice is to take advantage of the tolerance, and make the coin, on the average, somewhat light, within the legal limit; the amount thus gained to the Treasury being regularly accounted for. But in the United States the aim is to make the coinage conform to the standard weight and fineness, as nearly as practicable; and the general accuracy is far within the limits of tolerance, which, in fact, are proposed to be drawn closer in a draft of a law prepared by the Treasury Department.

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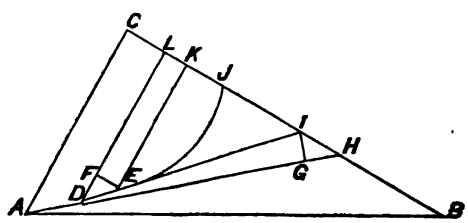
2. To find a General Formula for the Length of Curves of Pursuit. By Joseph Ficklin, of Columbia, Missouri.



Let the body pursued move uniformly from B toward C along the straight line BC, and let the pursuing body move uniformly along the curve $ADEJ$.

Put $\theta = ABC$, $a = AB$, $w = BL$, $x = BH$, $y = DH$, $s = AD$, $s' = ADEJ$; then $-KL = -EF = dw$, $HI = dx$, $-(GH + DE) = dy$, $DE = ds$. Since the triangles DEF and GHI are similar, we have $ds : -dw :: dx : GH$; whence $GH = -\frac{dwdx}{ds}$. But $dx = nds$; $\therefore GH = -ndw$, and $dy = -(-ndw + ds) = ndw - ds$. Integrating, we have $y = nw - s + c \ldots (1)$. When $y = a$, $s = o$, and $w = BC = a\cos\theta$; $\therefore a = na\cos\theta + c$; whence $c = a - na\cos\theta$, and (1) becomes $y = nw - s + a - na\cos\theta \ldots (2)$.

To find the length of the curve $ADEJ$, we observe that, when $y = o$, $s = s'$ and $w = ns'$; $\therefore o = n^2s' - s' + a - na\cos\theta$; whence

$$s' = \frac{a(1 - n\cos\theta)}{1 - n^2} \ldots (3).$$

If $\theta = 90^\circ$, (3) gives

$$s' = \frac{a}{1 - n^2} \ldots (4).$$

If $n = 1$, then $s' = \infty$.

If $\theta = o$, then $s' = \frac{a(1-n)}{1-n^2} = \frac{a}{1+n}$.

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3. On the Rates of Interest realized to Investors in the Securities of the United States. By E. B. Elliott, of Washington, D.C.

(Abstract.)

After stating the principles upon which the calculations were based, he proceeded to give the results of his investigations.

In the early part of the present century the credit of the United States Government was comparatively low, its eight per cent and six per cent securities being placed upon the market on terms such as to fix the rates realized to investors in general at from seven and two-tenths (7.2), to eight and seven-tenths (8.7), per cent; one of the loans, however, being placed upon the market, in the year 1812, at as low a realized rate as six per cent, while the rate realized on another loan was, in the year 1816, as high as nine and one-tenth (9.1) per cent.

The difficulties attendant upon the war of 1812 had an impor-

tant influence in disturbing the credit of the Government, and producing these comparatively high rates of interest.

In 1821, the credit of the Government had so far improved, that it was able to place a five per cent bond on the market, on terms such as to indicate the realized rate of interest to be but about four and one-quarter (4–22) per cent.

In the years 1854 and 1855, the five per cent securities of the Government sold in the open market in New York at such premium as to show the rate of interest realized nearly identical with the above; to wit, 4–22 and 4–24 per cent.

The market price of the six per cent securities of the Government in the same years indicated a still lower rate of realized interest; to wit, 3.29 and 3.27 per cent, respectively. In 1859, the five per cent securities of the Government sold in open market at prices indicating a realized rate of interest of four and one-half (4.59) per cent, and its six per cent securities at prices realizing only about three and one-half (3.41) per cent interest to the investors. In 1860, the prices of the six per cent securities indicated a rate of interest realized of about 5.02 per cent. These rates of interest indicate that the borrowing power of the Government during periods of tranquillity — that is, that its normal borrowing power — varies from three and one-fourth (3.27) per cent, to four and one-half (4.57) or five (5.02) per cent.

Passing from this period of comparative political quiet to the commencing year of our late civil war, we find the market prices of the five per cent securities to have been during the first few months of the year 1861 — the commencing year of the war — such as to imply a rate of interest realized to investors somewhat in excess of eight (8.14) per cent. Later in the same year, six per cent securities of the Government, known as the twenty year bonds of 1861–81, were sold in the open market at prices which indicated the realized rates of interest to vary from seven and one-half (7.59) to six and one-half (6.54) per cent. Passing by the succeeding years of active hostilities, concerning which the investigation is not as yet completed, we find in January, February, and March of the year 1869, the prices of the five per cent securities, known as the 10–40s of 1864, such as to show the rates of interest realized to have been about six and one-half per cent; varying, from an average of 6.69 per cent for the month of January, 6.53 per cent for the month of February, and 6.44 for the month of March of that year.

Passing to the year 1871, we find the credit of the Government to have improved, the carefully prepared average of the daily quotations of the several securities of the Government showing the average rates of interest realized to have varied from 4.93 to 6.05 per cent, according to the character of the security; the rates realized on the Pacific Railroad bonds — securities of which, both interest and principal, are payable in currency — averaging somewhat less than five per cent (4.93 to 4.98 per cent); on the five per cent 10–40s of 1864, slightly in excess of five per cent (5.11); on the coupon 5–20s of 1862, 5.96, and on the 5–20s of 1864–67–68, from 6 to 6.05 per cent.

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4. An Inquiry concerning the Physical Relation between the Masses and Mean Distances of the Different Planets. By John N. Stockwell, of Cleveland, Ohio.

Before writing my memoir on the secular inequalities of the planetary orbits, I was led to make some critical comparisons between the results of the different solutions, not only for the purpose of testing the general accuracy of the work, which had already been done by means of independent duplicate computations from analytical formulæ, but also for the purpose of ascertaining to what extent the values of the constants which I had obtained would be modified by employing different values of the planetary masses. This comparison led to the detection of a very curious and unexpected anomaly in the results obtained, and the explanation of the anomaly in question seems to point to a very interesting and useful application of the theory of maxima and minima to the determination of the different planetary masses. But, before proceeding to the special subject of this paper, it may be well to indicate very briefly the method which I have followed in my investigations.

A perfect determination of the secular inequalities of the planetary orbits requires that the elements, or data, employed in the development of the problem, should also be perfect. Some of these elements are invariable: the others are continually changing;

but it is sufficient for our purpose to know their values at any given epoch. The invariable elements of the problem are the masses and mean distances of the planets: the variable elements refer to the forms of their orbits, and to their positions in space. In the present state of astronomy, the elements of our problem are very approximately known, with the single exception of one of the invariable elements, — namely, that of the planetary masses, — which are not very perfectly known. The mass of the planet *Jupiter* is the only one that has been well determined, while the masses of all the other planets are uncertain to a considerable extent.

Such being the condition of our data, it is obvious that the best way to treat the problem is to assume certain values for the masses of the different planets, and substitute them in the analytical formulæ which determine the relations subsisting between the quantities sought and those already known. In this way we obtain a system of constant quantities of the same degree of accuracy as the masses used in the solution of the equations. If we, then, suppose the mass m of one of the planets to be greater or less than its assumed value, by any quantity, Δm, the masses of all the other planets remaining unchanged, and repeat the solution of our equations, we shall have a second system of constant quantities which would differ from the first, by quantities depending on the assumed increment Δm to the mass m. Let us, then, suppose that the mass m receives increments of $2\Delta m$, $3\Delta m$, &c., successively, and that we determine the resulting constants on each of these suppositions. It is evident that the successive sets of constants will differ from those depending on the assumed values of the masses by quantities due to the successive increments Δm, $2\Delta m$, $3\Delta m$, &c. If we, then, tabulate the values of the constants which we have obtained, which we will designate by c, c', c'', c''', &c., we may write the results in this form: —

	Diff.		Diff.
m	Δm	c	$c' - c$
$m + \Delta m$	Δm	c'	$c'' - c'$
$m + 2\Delta m$	Δm	c''	$c''' - c''$
$m + 3\Delta m$	Δm	c'''	$c^{iv} - c'''$
&c.		&c.	

Now, if the differences of the functions $c' - c$, $c'' - c'$, &c., are all equal to each other, they show that the variation of the function c

is strictly proportional to the variation of the mass m, at least, within the limits of the variation of the mass m which is covered by our computation. But if there are second differences to the function, having a magnitude comparable with the first differences, they indicate the approach of the function towards a condition of maxima or minima; and the explanation of these conditions has led to the inquiry indicated by the title of this paper. I will now proceed more particularly to this special inquiry.

In making choice of the masses which I have adopted as the basis of my computation, I had no discriminating conditions to satisfy in advance; and I therefore assumed those which are given in the "Nautical Almanac," except for the mass of the earth, as being as reliable as any that it was possible to obtain. In deducing a new value for the earth's mass, I was misled by the results of the Astronomical Expedition to South America, which seemed to indicate a diminution of the sun's parallax; whereas, later determinations show that it should have been increased. The value of the earth's mass, which I employed, was therefore suspected to be considerably too small; and to remedy this defect I was induced to repeat the computation by using a double increment to the assumed mass of the earth.

The mass of the earth which I employed, and designated as "*assumed mass*," was, $m''_0 = \frac{1}{3\,6\,8\,6\,8\,9}$ of the sun's mass. I then repeated the computation by increasing the mass of the earth successively by $\frac{1}{20}$ and $\frac{2}{20}$. The element deduced from these different assumptions, which I compared, was the superior limit of the eccentricity of the earth's orbit. For these several hypotheses I get the following values: —

Mass.	Diff.	Superior limit of e''.	1st Diff.	2d Diff.
m''_0		0.067735		
	$\frac{1}{20}\, m''_0$		+ 0.001654	
$m''_0 (1 + \frac{1}{20})$		0.069389		— 0.001394
	$\frac{1}{20}\, m''_0$		+ 0.000260	
$m''_0 (1 + \frac{2}{20})$		0.069649		

In making this comparison, I was much surprised to find that the limit of the eccentricity increased by 0.001654, when the mass was increased by $\frac{1}{20}$, and was increased only 0.001914 when the mass was increased twice as much. I first suspected that there must be some mistake in the computations, and therefore very carefully examined them, and satisfied myself that the computa-

tions were all correct. I then concluded to increase the earth's mass by $\frac{3}{20}$, and repeat the whole computation so as to be perfectly sure that no systematic error had crept in. The comparison then stood as follows:—

	Diff.	e''	1st Diff.	2d Diff.	3d Diff.
m_0		$=0.067735$			
$m_0(1+\frac{1}{20})$	$\frac{1}{20}m_0$	$=0.069389$	$+0.001654$	-0.001394	
$m_0(1+\frac{2}{20})$	$\frac{1}{20}m_0$	$=0.069649$	$+0.000260$	-0.001820	-0.000426
$m_0(1+\frac{3}{20})$	$\frac{1}{20}m_0$	$=0.068089$	-0.001560		

This fourth computation not only confirmed the accuracy of the other computations, but demonstrated the fact that a certain value of the earth's mass, which is included within the limits of $\frac{1}{338338}$th and $\frac{1}{332800}$th of the sun's mass, would permit the earth's orbit to become more eccentric from the perturbations of the other planets of the system than any other value of the earth's mass. I find by calculation that the value of the earth's mass which renders e'' a maximum is $m''=\frac{1}{340299}$. This corresponds to a solar parallax of 8″.730; a value approximating towards some of the more recent determinations of that element.

The preceding investigation suggested the following question: *Is it not possible that the constitution of the solar system is such that the mass of each planet is so adjusted to its mean distance as to permit greater oscillations in the eccentricity of its orbit than any other mass moving at the same distance?*

In order to test this question, I examined into the effect which small changes in the mass of *Jupiter* would have on the extreme variations in the form of his orbit. I selected this planet because his mass had been well determined from the motions of his satellites. I conceived that, if only very slight changes in his estimated mass were required, in order to render his elements conformable to the preceding hypothesis, then we might regard the hypothesis as legitimate, and be justified in applying it to the other planets. But calculation showed that no admissible variation in his mass would suffice to render his elements accordant with the hypothesis. I therefore abandoned the hypothesis, and sought for another, which, if not perfectly legitimate, had at least the merit of greater physical significance.

My second hypothesis is enunciated in the following proposition, viz.;—*The mass of each planet is so adjusted to its mean distance*

as to permit greater variations in its living force than any other mass moving at the same distance.

Since the living force of a body is equal to the product of its mass by the square of its velocity, if we denote the masses of the planets by m, m', m'', &c., and their velocities by v, v', v'', &c., the living forces of the different planets will be expressed by mv^2, $m'v'^2$, $m''v''^2$, &c. If the transverse axis of an ellipse be denoted by $2a$ and its eccentricity by e, the circumference will be equal to $2\pi a\{1-\frac{1}{4}e^2\}$; and, if we divide this by the periodic time of a planet having the mean distance a from the sun, we shall obtain the mean velocity of the planet. Now the periodic time of a planet is equal to $2\pi a^{\frac{3}{2}}$, and is independent of the eccentricity of its orbit. The mean velocity of the planet is therefore equal to

$$v=\frac{1}{\sqrt{a}}\{1-\tfrac{1}{4}e^2\}. \quad (1)$$

Whence the living force of the planet is given by the equation

$$mv^2=\frac{m}{a}\{1-\tfrac{1}{2}e^2\}. \quad (2)$$

From this equation it follows that the living force of a planet is a maximum when the eccentricity is a minimum, and a minimum when the eccentricity is a maximum. If we denote the minimum and maximum values of the eccentricity by e_0 and e_1, respectively, the greatest variation of the living force depending on the eccentricity will be given by the equation

$$\Delta(mv^2)=\frac{m}{a}\{e_1^2-e_0^2\}. \quad (3)$$

And if the mass m is determined so that this function shall be the greatest possible, we shall have

$$\Delta\frac{(mv^2)}{\Delta m}=0; \quad (4)$$

In the application of this formula to the earth, we observe that the lower limit of the eccentricity of its orbit is equal to nothing; consequently $\frac{m''}{a''}e''^2_1$ is to be a maximum. We shall therefore have the following tabular values of this function with their differences:

Mass.	$10^{10}\frac{m''}{a''}e''^2_1$	1st Diff.	2d Diff.	3d Diff.
m''_0	124.4421			
		+ 12.6805		
$m''_0(1+\frac{1}{20})$	137.1226		— 5.0723	
		+ 7.6082		— 2.6572
$m''_0(1+\frac{2}{20})$	144.7308		— 7.7295	
		— 0.1213		
$m''_0(1+\frac{3}{20})$	144.6095			

We find that this gives a maximum when the mass is equal to $m''_0(1+\frac{2.1888}{20})$, and consequently $m''=\frac{1}{3277.41}$, which corresponds to a solar parallax of 8″.8111.

If the same process be applied to the elements of *Jupiter's* orbit, we find no indications of a maximum for any admissible variation of his mass; and, consequently, the second hypothesis was a failure.

My third hypothesis may be enunciated as follows: *The masses of planets are so adjusted to their mean distances as to permit greater variations in the living forces of the bodies of the system, than would be possible from any other system of masses moving at the same distances.*

This proposition may be readily demonstrated if we are permitted to assume, *à priori*, that the planetary system is so constituted as to insure to itself a greater degree of stability against the action of foreign forces than would be possible from any other arrangement of the system.

I shall now proceed to show that the masses of the *Earth* and *Venus* favor the preceding hypothesis; but it is important to observe that we cannot apply the mass of *Jupiter* as a test of its correctness, since it is the stability of the system that is now required; whereas in the two preceding hypotheses the inquiry related to the stability of particular planetary orbits.

In this investigation it is important to observe that we cannot determine the actual mass of any of the planets, but only the ratio of the different planetary masses, in the same manner that Kepler's third law determines the relative distances of the different planets from their mean motions. But when the mass of one of the planets has been in any way determined, the relation between the different planetary masses serves to determine them all. The reason of this indetermination is this: — The magnitude of the secular inequalities does not depend upon the actual masses of the planets, but simply upon the ratio of the masses to each other; so that if all the masses were to be increased or diminished in the

same ratio, the magnitude of the secular inequalities would remain unchanged.

I have therefore supposed that the mass of *Jupiter* is accurately known, although it may possibly be in error to the extent of its *one-thousandth* part; and shall endeavor to assign such masses to the other planets as will insure to the system the condition of maximum permanence.

If we suppose the letters in equation (2) to refer to the planet *Mercury*, and mark them with one, two, three, &c., accents to designate the same quantities relative to *Venus*, the *Earth*, *Mars*, &c., we shall have the following system of equations for computing the living force of the system, which are correct to quantities depending on the third power of the eccentricities: —

$$\left.\begin{aligned} mv^2 &= \frac{m}{a}\left\{1-\tfrac{1}{2}e^2\right\} && \text{Living force of Mercury.}\\ m'v'^2 &= \frac{m'}{a'}\left\{1-\tfrac{1}{2}e'^2\right\} && \text{Living force of Venus.}\\ m''v''^2 &= \frac{m''}{a''}\left\{1-\tfrac{1}{2}e''^2\right\} && \text{Living force of the Earth.}\\ &\text{\&c.} \end{aligned}\right\} \quad (4)$$

If we add all these equations together, we shall obtain the expression for the living force of the whole system, as follows: —

$$\left.\begin{aligned} \Sigma mv^2 = &\left\{\frac{m}{a}+\frac{m'}{a'}+\frac{m''}{a''}+\text{\&c.}\right\}\\ &-\tfrac{1}{2}\left\{\frac{m}{a}e^2+\frac{m'}{a'}e'^2+\frac{m''}{a''}e''^2+\text{\&c.}\right\} \end{aligned}\right\} \quad (5)$$

But since the living force of the whole system, or the sum of the living forces of the bodies of the system is constant, we shall have

$$\frac{m}{a}+\frac{m'}{a'}+\frac{m''}{a''}+\text{\&c.} = \text{constant}, \quad (6)$$

and

$$\frac{m}{a}e^2+\frac{m'}{a'}e'^2+\frac{m''}{a''}e''^2+\text{\&c.} = \text{constant}. \quad (7)$$

Whence it follows that the living force of a system of bodies moving in circular orbits is a maximum; and if the orbits are all circular at a given epoch, they will always remain so, unless acted upon by forces foreign to the system; in which case the living

force of the system is diminished. But this is not the result in a system of elliptical orbits. The living force of the system is not necessarily diminished by the action of a foreign force; since the variation of living force of the different bodies of the system may be balanced by changing the eccentricities in such manner that the constancy of the living forces will be maintained.

Since the first term of the second member of equation (5) is constant, the second term must also be constant, and we shall have equation (7). This equation is analogous to the celebrated equation discovered by La Place, — an equation showing that the relation between the masses, the square roots of the mean distances, and the squares of the eccentricities, remains always the same. But equation (7) is more general than the one discovered by La Place, which was restricted to the condition that all the bodies should revolve in the same direction; whereas equation (7) shows that the eccentricities, if once small, will always remain so, whether the bodies all revolve in the same direction or not.

Translated into ordinary language, equation (5) enunciates the following theorem: —*If the mass of each planet be multiplied by the product of the square of its velocity by the square of the eccentricity of its orbit, the sum of such products always retains the same magnitude.*

Now, denoting the minimum and maximum eccentricities of *Mercury's* orbit by e_0 and e_1 respectively, and accenting the same letters for the same quantities relating to the other planets, we shall find —

$$\left.\begin{aligned} \Delta(mv^2) &= \tfrac{1}{2}\,\frac{m}{a}\left\{ e^2{}_1 - e^2{}_0 \right\}, \\ \Delta(m'v'^2) &= \tfrac{1}{2}\,\frac{m'}{a'}\left\{ e'^2{}_1 - e'^2{}_0 \right\}, \\ \Delta(m''v'') &= \tfrac{1}{2}\,\frac{m''}{a''}\left\{ e''^2{}_1 - e''^2{}_0 \right\}, \\ &\text{\&c.} \quad (8) \end{aligned}\right\}$$

Maximum Variation of *Mercury's* living force.
Maximum Variation of *Venus's* living force.
Maximum Variation of *Earth's* living force.

Neglecting to notice the signs in these variations, and taking their sum, we shall find —

$$\Delta(mv^2) + \Delta(m'v'^2) + \Delta(m''v''^2) + \text{\&c.} = \tfrac{1}{2}\left\{ \frac{m}{a}(e^2{}_1 - e^2{}_0) + \right.$$

$$\left. \frac{m'}{a'}(e'^2{}_1 - e'^2{}_0) + \frac{m''}{a''}(e''^2{}_1 - e''^2{}_0) + \text{\&c.} \right\}. \quad (9)$$

A_1, A_2, A_3

Now it is evident that that distribution of planetary masses which permits the greatest variation in the living forces of the bodies of the system is that which secures the condition of maximum permanence to the system. The condition of maximum permanence is therefore satisfied when the masses are determined so as to satisfy the following equations:—

$$\left.\begin{aligned} \frac{\Delta\left\{\frac{m}{a}(e^2_1-e^2_0)+\frac{m'}{a'}(e'^2_1-e'^2_0)+\frac{m''}{a''}(e''^2_1-e''^2_0)+\&c.\right\}}{\Delta m} &= 0, \\ \frac{\Delta\left\{\frac{m}{a}(e^2_1-e^2_0)+\frac{m'}{a'}(e'^2_1-e'^2_0)+\frac{m''}{a''}(e''^2_1-e''^2_0)+\&c.\right\}}{\Delta m'} &= 0, \\ \frac{\Delta\left\{\frac{m}{a}(e^2_1-e^2_0)+\frac{m'}{a'}(e'^2_1-e'^2_0)+\frac{m''}{a''}(e''^2_1-e''^2_0)+\&c.\right\}}{\Delta m''} &= 0. \\ \&c. \end{aligned}\right\} \quad (10)$$

We shall now apply the preceding theory to the determination of the masses of the *Earth* and *Venus*, these being the only planets whose masses have yet been thus determined.

The computed values of the variable part of the living forces of the planets, for four different values of the earth's mass, are as follows:—

	m''_0	$m''_0 \times (1+\frac{1}{20})$	$m''_0 \times (1+\frac{2}{20})$	$m''_0 \times (1+\frac{3}{20})$
$(m \div a)(e^2_1 - e^2_0) \times 10^{10}$	206.701	205.064	203.292	201.002
$(m' \div a')(e'^2_1 - e'^2_0)$	176.853	193.749	206.001	208.634
$(m'' \div a'')(e''^2_1 - e''^2_0)$	124.442	137.123	144.731	144.610
$(m''' \div a''')(e'''^2_1 - e'''^2_0)$	46.915	48.135	48.532	48.941
$(m^{iv} \div a^{iv})(e^{iv2}_1 - e^{iv2}_0)$	5594.540	5594.412	5594.261	5594.112
$(m^{v} \div a^{v})(e^{v2}_1 - e^{v2}_0)$	2083.246	2083.292	2083.339	2083.368
$(m^{vi} \div a^{vi})(e^{vi2}_1 - e^{vi2}_0)$	124.333	124.290	124.244	124.198
$(m^{vii} \div a^{vii})(e^{vii2}_1 - e^{vii2}_0)$	3.181	3.180	3.179	3.178
Sum $= s =$	8360.211	8389.245	8407.579	8408.043

We may tabulate these sums as follows:—

m''	Diff.	s.	1st Diff.	2d Diff.	3d Diff.
m''_0	$\frac{1}{20} m''_0$	8360.211	+ 29.034		
$m''_0(1+\frac{1}{20})$	"	8389.245	+ 18.334	− 10.700	
$m''_0(1+\frac{2}{20})$	"	8407.579	+ 0.464	− 17.870	− 7.17
$m''_0(1+\frac{3}{20})$	"	8408.043			

The function s is evidently a maximum when $m''=m''_0(1+\frac{2.5}{26})$, very nearly. An exact calculation shows that the maximum occurs when $m'' = m''_0\,(1 + \frac{2.5345}{26}) = 1.126767\, m''_0 = \frac{1}{327210}$ of the sun's mass.

According to this calculation, the mass of the earth is $\frac{1}{327210}$th of the mass of the sun. Strictly speaking, this is the sum of masses of the moon and earth, and corresponds to a solar parallax of 8″.8159, on the supposition that the moon's parallax is 3422″.06, and that her mass is equal to $\frac{1}{80}$th of the earth's mass.

Let us now compare this result with the values deduced from observations made especially for the purpose of determining the sun's distance, and which possess all the precision and delicacy that has been found possible to attain in making such observations.

The transits of *Venus* in 1761 and 1769, according to Professor ENCKE's discussion, gave the following values of the solar parallax:—

Transit of	1761	gave	8″.49	for sun's parallax.	
„	„ 1769	„	8″.59	„	„ „

The values differ to the extent of 0″.10 of a second from each other.

By combining the two transits, ENCKE obtained 8″.571 for the sun's parallax; and the following little table shows the value obtained for the same element, according to different calculators, by the discussion of the same observations.

Sun's parallax deduced from the transits of *Venus* in 1761 and 1769:—

Sun's Parallax, from transits of *Venus*.	8″.571	according to ENCKE.
	8″.832	„ „ POWALKY.
	8″.87	„ „ NEWCOMB.
	8″.91	„ „ STONE.

Other values were obtained by different investigators; but the preceding are supposed to be the most correct that could be obtained. They suffice to indicate the degree of uncert[illegible] attaching to that element, and the difficulty attending [illegible] improvement.

The preceding values depend wholly on observati[illegible] now proceed to give the values that have been de[illegible] lunar and solar motions, from observation and theo[illegible]

Sun's Parallax, from motions of *Sun* and *Moon*.	8″.56	according to	La Place.
	8″.916	„	„ Hansen.
	8″.95	„	„ Le Verrier.
	8″.91	„	„ „ corrected by Stone.
	8″.84	„	„ Newcomb.

The values of the parallax, according to observations, combined with the theories of the motions of the sun and moon, give, on the whole, a larger parallax than that derived from the transits of *Venus*; but the difference is very small.

Another method of finding the sun's parallax depends upon the motion of *Mars* in right-ascension, as affected by the rotation of the earth. Without stopping to explain the nature of this method, I must content myself with simply giving the results that have been obtained.

Sun's Parallax, from observations of *Mars*.	8″.943	according to	Stone.
	8″.964	„	„ Winnecke.
	8″.855	„	„ Newcomb.

Lastly, I shall give the values of the sun's parallax according to the experimental measures of the velocity of light, by Fizeau and Foucault. The time required by light to pass over the distance of the earth from the sun has been deduced from the eclipses of *Jupiter's* first satellite, and from the phenomena of aberration. These two estimates are somewhat different, and it is therefore necessary to assign the distance or parallax corresponding to each determination. If we multiply the velocity of light by the time required for its passage from the sun to the earth, we shall evidently have the distance of the earth from the sun, from which the parallax is easily deduced. Now the velocity of light, according to the experiment of Fizeau, is 194,600 miles per second; while, according to the experiment of Foucault, it is only 185,300 miles in a second. According to Delambre's discussion of more than one thousand eclipses of *Jupiter's* first satellite, the time required for light to pass over the mean distance of the earth from the sun is 493′.198 seconds. Multiplying the preceding velocities by this number, and dividing the earth's radius by their product, we shall obtain the sine of the sun's parallax.

Sun's Parallax.

FOUCAULT'S velocity	8″.9440	Combined with time of passage of light from sun to the earth, as deduced from eclipses of *Jupiter's* satellites.
FIZEAU'S velocity	8″.5165	

According to the phenomena of aberration, light requires 497.827 seconds to pass from the sun to the earth. We must therefore multiply the preceding velocities by this number, and divide by their products as before, and we shall find the sun's parallax as follows:—

Sun's Parallax.

FOUCAULT'S velocity	8″.8608	Combined with time of passage of light from sun to the earth, according to the phenomena of aberration.
FIZEAU'S velocity	8″.4374	

If we now take the arithmetical mean of all these various determinations, we shall find that the sun's parallax is 8″.805, which differs only *one-ninetieth of a second* from my theoretical value of the parallax. This near agreement is, perhaps, accidental; but still this comparison suffices to show that, so far at least as the earth is concerned, the preceding hypothesis accords well with observation.

Let us now determine the mass of *Venus* by the same method, and compare our result with the various determinations by other methods.

The assumed mass of *Venus* is $m'_0 = \frac{1}{390000}$; and I have computed the terms of equation (9) for increments of $\frac{1}{20} m'_0$, $\frac{2}{20} m'_0$, $\frac{3}{20} m'_0$, and $\frac{4}{20} m'_0$; and find the following results for the various hypotheses:—

	s.	1st Diff.	2d Diff.	3d Diff.
m'_0	8360.211			
		+ 61.951		
$m'_0 (1 + \frac{1}{20})$	8422.162		— 26.726	
		+ 35.225		+ 3.354
$m'_0 (1 + \frac{2}{20})$	8457.387		— 23.372	
		+ 11.853		+ 0.745
$m'_0 (1 + \frac{3}{20})$	8469.240		— 22.627	
		— 10.774		
$m'_0 (1 + \frac{4}{20})$	8458.466			

From these numbers we deduce a maximum for s when the mass $m' = m'_0 (1 + \frac{3}{20}) = 1.155\, m'_0 = \frac{1}{337800}$th of the sun's mass.

To compare this mass of *Venus* with observations, I find that the following values have been found by different calculators for the mass of this planet:—

$m' = \frac{1}{356632}$ according to DELAMBRE.
$m' = \frac{1}{349440}$ " " LINDENAU.
$m' = \frac{1}{356632}$ " " LA PLACE.
$m' = \frac{1}{401211}$ " " BURGHARDT.
$m' = \frac{1}{401847}$ " " AIRY.
$m' = \frac{1}{390000}$ " " LE VERRIER.
$m' = \frac{1}{386308}$ " " ROTHMAN.

From this statement it appears that my theoretical value of the mass of *Venus* exceeds, by a very small quantity, all the values of the mass of this planet which have been deduced from observations. But this circumstance need excite no surprise, when we remember that the recent correction to the mass of *Jupiter* implies an increase of his mass, by a quantity *two and one-half* times greater than the combined masses of all the planets within his orbit.

These are the only two planets whose masses I have yet been able to determine theoretically. Owing to the great length and intricacy of the calculations, I have not been able to complete the calculations for the other planets of the system; but I have carried them to a sufficient extent to show that the recognized values of the masses of the three planets, outside of *Jupiter's* orbit, are considerably too small to bring them into harmony with *Jupiter's* mass, so as to satisfy the condition of maximum permanence for the system. I have satisfied myself of the correctness of this statement in two different ways. *First*, by increasing each of those planetary masses by finite increments, as already explained, and then increasing them simultaneously by the same quantities; and, *second*, by diminishing the mass of *Jupiter*. I find that the effect of diminishing the mass of *Jupiter*, on the expression of the variable part of the living force of the system, is the same as an increase of the planetary masses that circulate beyond him. But in regard to the limits of increase to the masses of *Saturn*, *Uranus*, and *Neptune*, I cannot speak with any degree of certainty. That there is a limit does not admit of a doubt; and the fact that a decrease of *Jupiter's* mass has the same effect as an increase of the planetary masses beyond him shows simply that the recognized values of the four most distant planetary masses do not harmonize with the principle on which my calculations are founded. Whether any admissible changes in the recognized values of the three outer planetary masses will bring the system into harmony remains yet to be determined.

Now, without positively affirming that my explanation of the physical significance of these conditions of maxima is correct, we may safely conclude that they cannot be meaningless, and that the correct interpretation of them will extend our knowledge of the manner in which cosmical forces operate in the formation of isolated stellar and planetary systems.

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5. Longitude Determination across the Continent. By George W. Dean, of Fall River, Mass.

With the permission of Professor Peirce, Superintendent of the United States Coast Survey, I offer to the Association a brief statement in regard to the method used and the results obtained by the Coast Survey, in determining the longitude of San Francisco, and several intermediate points, by telegraphic exchange of clock signals with Harvard College Observatory, Cambridge, Massachusetts.

In November, 1862, I was requested by the late Professor Bache to obtain such information as might be practicable, in regard to the construction of the telegraph lines across the Continent, with the view of determining by the telegraphic method the difference of longitude between the Atlantic and Pacific coasts.

He, at the same time, requested me to make a series of experiments with "relay magnets," generally known as "*telegraph repeaters*," for the purpose of measuring approximately the time required for transmitting a signal through one or more of those instruments.

The results of those preliminary experiments were inserted by the Professor in the Appendix of his Annual Report for 1863, and the final results in his Report for the year 1864.

I was greatly indebted to the present distinguished Secretary of the Smithsonian Institution, Professor Henry, for the success attending the experiments with "relay magnets," in 1863–64; and it is gratifying that the results then obtained have, in

some degree, aided in modifying and improving the construction of the telegraph instruments now in general use in the United States.

In October, 1868, I was directed by the Superintendent, Professor Peirce, to make the requisite arrangements for determining, by telegraphic exchange of clock signals, the difference of longitude between Harvard College Observatory and one of the Coast Survey Stations on the Pacific coast, and to prepare a programme for conducting the operations.

The general outline of the plan was to establish an Astronomical Station at Omaha, Nebraska, which is, by the telegraph rate, about 1,550 miles from Cambridge; also a Station at Salt Lake City, Utah, which is located about 1,050 miles west of Omaha, and 950 miles east of San Francisco.

Professor Winlock, Director of Harvard College Observatory, co-operated with the Coast Survey, by placing his astronomical instruments at the service of the Superintendent, and directing the telegraphic longitude operations at Cambridge.

The observations for determining the clock and instrumental corrections at Cambridge were made chiefly by Assistant A. T. Mosman and Sub-Assistant F. Blake, Jr.

At Omaha, the clock and instrumental corrections were determined by Assistant Edward Goodfellow, and Mr. E. P. Austin, who used a forty-six-inch transit with an aperture of two and three-fourths inches.

All the observations were recorded by an astronomical clock, in connection with a chronograph register.

At Salt Lake City, the clock and instrumental corrections were determined by myself, assisted by Mr. F. H. Agnew, Sub-Assistant in the Coast Survey.

The instruments used were similar to those provided for the Stations at Omaha and San Francisco.

Assistant George Davidson had charge of the longitude operations at San Francisco, and co-operated with Professor Winlock and myself in making the telegraphic longitude determinations across the Continent.

Cold, dry weather being most favorable for exchanging telegraph signals between distant stations, arrangements were made for these experiments during the winter of 1868–69.

Whenever the weather permitted, the clock and instrumental corrections at each station were carefully determined immediately

before and after the exchange of clock signals between the several stations.

For this purpose a series of eight or ten standard zenith, and two or three circumpolar stars were observed, one-half with the lamp-end of the axis *east*, and an equal number with the lamp *west*.

In such a series, the probable error of the result for clock correction, in no case, exceeded 0.05 seconds.

Mayer's formulæ, by application of the method of least squares, have been used in these reductions, which have been made in the most satisfactory manner by Captain Isaac Bradford, of Cambridge.

The formulæ and a single example, for the purpose of illustrating the general arrangement of the reductions, are given with the abstract of longitude results.

In closing this paper, I will state that, on the nights of February 28th and March 7th, 1869, the Western Union Telegraph Company, with their usual liberality for the advancement of science, placed two of their telegraph lines between Cambridge and San Francisco at the service of the Coast Survey, for the purpose of measuring the "transmission time" of signals sent from Cambridge to San Francisco and returned, and *vice versâ*.

The entire length of the several circuits, which were composed chiefly of No. 9 iron wire, was about 7,200 miles; and the number of "*telegraph repeaters*" used was thirteen.

The results were very satisfactory, and accorded closely with the "double transmission time" deduced from the longitude determinations between Cambridge and San Francisco, and also with the results of the experiments made for "transmission time," with a single wire between those points, by Professor Winlock and Assistant Davidson.

FORMULÆ USED IN THE REDUCTIONS.

Star.
Lamp.
Tallies.

α

δ

M — Mean of Tallies.

F — „ „ Thread Intervals.

$\log. F$

$\log. \sec. \delta$

$\log. \rho$ — ρ is the correction for rate, and its log. is 0.000005 for a gain of 1 sec. daily : 0.00119 for a mean time clock.

$\log. \sigma$ — σ is the sine correction : log. σ being additive to log. F; when F sec. δ is less than 2^m it may be neglected.

$\log. R.$

$R.$ — $R = F. \sec. \delta. \sigma. \rho.$; and is to be added to M to obtain the Time of Transit over the mean of all the Threads.

b_0 — b_0 = the level correction in time, corrected for inequality of pivots : it is positive for $W.$ end high.

$A.$ — $A = \dfrac{sin.\ (\phi - \delta)}{cos.\ \delta}$

$B.$ — $B = \dfrac{cos.\ (\phi - \delta)}{cos.\ \delta}$

$C.$ — $C = \sec. \delta$

$180^0 - \delta$ being used instead of δ when the star is below the pole.

κ — κ = The Diurnal aberration $= 0^s.021 \cos. \phi \sec. \delta$. It is (−) in upper, (+) in lower culminations.

Bb_0

T — $T = M + R.$

t — $t = T + Bb_0 + \kappa$

ω — $\omega = \alpha - t = \Delta t + Aa \pm Cc$

Cc

ω_0 — $\omega_0 = \omega \mp Cc$, upper sign for lamp west.

The Collimation Constant (c) is determined from reversals in circumpolar stars, and is to be obtained from the equation

$$t_e - t_w = \omega_w - \omega_e = 2Cc.$$

$A.$ is positive, except for stars between the Zenith and North Pole.

$B.$ „ „ „ at lower culmination.

$C.$ „ „ „ „ „

The local time and azimuth are obtained thus : Assume an approximate value of the clock correction $= \theta$ for an arbitrary time T_0, and call $\omega - \theta = \omega'$. If the Collimation is known, and the corresponding corrections applied, we have only to reduce the value of ω_0 for the several stars to the time T_0, by applying the correction for daily rate. Thus :—

$$(\omega_0) = \omega_0 + \frac{t - T_\theta}{24 \text{ hr.}} \times \text{daily rate},$$

and we have, putting $\Delta\theta = \Delta t - \theta$,

$$\Sigma\ \Delta\theta + \Sigma\ Aa = \Sigma\ \omega'_0$$

$$\Sigma\ A.\ \Delta\theta + \Sigma\ A^2 a = \Sigma\ A\ \omega'_0$$

Whence we determine a, $\Delta\theta$, and thence Δt for the time T_0.

FEBRUARY 17th, 1869.

COLLIMATION.

STAR.	TIME.	$Cc.$	$C.$	$c.$
	h. m.			
ω Draconis L.C. . . .	5 37	+.001	—2.767	—.0004
ψ' Draconis L.C. . .	5 44	—.0805	—3.278	+.0246

$T_0 =$ h. 6. m. 46 s.

$\theta = +12.550$

Observer A. T. M.

CLOCK AND AZIMUTH CORRECTIONS.

STAR.	LAMP.	(ω_0)	$A.$	ω'_0	A^2	$A\omega'_0$	Aa	Δt
ω Draconis L. C. .	*W.-E.*	+12.246	+2.580	—.304	6.656	—.784	—.312	12.558
ψ Draconis (pr.) L.C.	*E.-W.*	+12.139	+2.976	—.411	8.857	—1.225	—.360	12.499
α Orionis	*W.*	+12.426	+ .578	—.124	.335	—.072	—.070	12.496
ζ Geminor	*W.*	+12.450	+ .455	—.100	.207	—.046	—.055	12.505
ε Can. Maj. . . .	*W.*	+12.452	+1.080	—.098	1.167	—.106	—.131	12.583
δ Can. Maj. . . .	*W.*	+12.420	+1.087	—.130	1.076	—.135	—.125	12.545
δ Geminor. . . .	*W.*	+12.474	+ .372	—.076	.139	—.028	—.045	12.519
α Can. Min. . . .	*E.*	+12.500	+ .602	—.050	.363	—.030	—.073	12.573
β Geminor. . . .	*E.*	+12.505	+ .276	—.045	.076	—.012	—.033	12.538
ϕ Geminor. . . .	*E.*	+12.497	+ .296	—.053	.088	—.016	—.036	12.533
			+10.252	—1.391	18.964	—2.452		12.535

$$10\,\Delta\theta + 10.252\,a = -1.391$$
$$+\ 10.252\,\Delta\theta + 18.964\,a = -2.452$$
$$\Delta\theta + 1.0252\,a = -.1391$$
$$+\ 10.252\,\Delta\theta + 10.510\,a = -1.426$$
$$+\ 8.454\,a = -1.026$$
$$a = -.121$$

$$\Delta\theta - .1240 = -.1391$$
$$\Delta\theta = -.015$$

$$\Delta t = +12.535 \pm .007$$

REDUCTIONS OF THE OBSERVATIONS FOR

FEBRUARY 17th, 1869.

Star.	ω DRACONIS L. C.		ψ DRACONIS (pr.) L. C.		∝ ORIONIS.	ζ GEMINOR.
Lamp. Tallies.	W. F. C.	E. E. F.	E. B. C.	W. C. B.	W. C. D. E.	W. C. D. E.
	h. m. s.		h. m. s.		h. m. s.	h. m. s.
∝	5.37.41.56		5.44.14.35		5.48.5.20	6.30.9.21
δ	+68°48′52″.0		+72°12′32″.9		+7°22′37″.5	+16°30′22″.4
M.	5.36.24.346	5.38.34.368	5.42.49.900	5.45.19.295	5.47.52.714	6.29.56.682
F.	+23.499	−23.499	+22.086	−23.519	+0.024	+0.024
log. *F*	1.37105	1.37105*n*	1.344058	1.37142*n*	8.38021	8.38021
log. sec. δ	0.442024	0.442024	0.514927	0.514927	0.00361	0.01828
log. ρ						
log. σ			02	02		
log. *R.*	1.813074	1.813074*n*	1.858987	1.886349	8.38382	8.39849
R.	+1.5.024	−1.5.024	+1.12.275	−1.16.975	+.024	+.025
b_0	+ .094	+.066	+.066	+.054	+.054	+.061
A.	+2.580		+2.976		+.578	+.455
B.	−1.000		−1.362		+.826	+.938
C.	−2.767		−3.273		+1.008	+1.043
κ	+.048	+.048	+.051	+.051	−.016	−.016
Bb_0	−.094	−.066	−.090	−.074	+.045	+.057
T	5.37.29.370	5.37.29.344	5.44.2.175	5.44.2.320	5.47.52 738	6.29.56.707
t	5.37.29.319	5.37.29.321	5 44.2.136	5.44.2.297	5 47.52.767	6.29.56.748
ω	+12.241	+12.239	+12.214	+12.053	+12.433	+12.462
Cc					−.012	−013
ω_0	+12.240		+12.134		+12.421	+12.449
(ω_0)	+12.246		+12.139		+12.426	+12.450

CLOCK AND INSTRUMENTAL CORRECTIONS.

FEBRUARY 17th, 1869 $\left\{\begin{array}{l} c = +.012 \\ \text{Hourly rate} = +.005 \end{array}\right.$

ε CAN. MAJ.	δ CAN. MAJ.	δ GEMINOR.	α CAN. MIN.	β GEMINOR.	ϕ GEMINOR.
W.	*W.*	*W.*	*E.*	*E.*	*E.*
C. D. E.	*C. D. E.*	*D.*	*E. D. C.*	*E. D. C.*	*E. D. C.*
h. m. s.	*h.m.s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
6.53.29.63	7.3.4.87	7.12.18.60	7.32.27.46	7.37.18.63	7.45.29.50
—28°48′2″.2	−26°11′29″.3	+ 22°13′8″.4	+ 5°33′19″.2	+28°20′18″.6	+27°6′2″.0
6.53.17.152	7.2.52.422	7.12.6.104	7.32.14.944	7.37.6.096	7.45.16.975
+0.024	+0.024	0.000	—0.024	—0.024	—0.024
8.38021	8.38021	— ∞	8.38021	8.38021	8.38021
0.05735	0.04705	0.03351	0.00205	0.05544	0.05051
8.43756	8.42726	— ∞	8.38226*n*	8.48565*n*	8.43072*n*
+.027	+.027		—.024	—.027	—.027
+.004	+.010	+.024	+.080	+.076	+.074
+1.080	+1.037	+.372	+.602	+.276	+.296
+.368	+.407	+1.014	+.801	+1.102	+1.084
+1.141	+1.114	+1.080	+1.005	+1.136	+1.123
—.018	—.017	—.017	—.016	—.018	—.017
+.002	+.004	+.024	+.064	+.084	+.080
6.53.17.179	7.2.52.449	7.12.6.104	7.32.14.920	7.37.6.069	7.45.16.948
6 53.17.163	7.2.52.436	7.12.6.111	7.32.14.968	7.37.6.135	7.45.17.011
+12.467	+12.434	+12.489	+12.492	+12.495	+12.489
—.014	—.013	—.013	+.012	+.014	+.013
+12.453	+12.421	+12.476	+12.504	+12.509	+12.502
+12.452	+12.420	+12.474	+12.500	+12.505	+12.497

LONGITUDE BETWEEN CAMBRIDGE AND OMAHA.

(Not corrected for personal equation.)

Date. 1869.	$\lambda + x_2$	Probable Error.	No. of Series of Signals	$\lambda - x_1$	Probable Error.	No. of Series of Signals.	Date. 1869.	2λ	Probable Error.	λ	Probable Error.	$x_1 + x_2$ Double Transmission Time.
	h. m. s.			*h. m. s.*				*h. m. s.*		*h. m. s.*		*s.*
Feb. 17	1.39.15.305	± .018	2	1.39.14.990	± .015	8	Feb. 17	3.18.30.295	± .028	1.39.15.147	± .012	.315
„ 18	15.233	± .033	2	14.960	± .030	2	„ 18	30.258	± .045	15.127	± .022	.333
„ 24	15.278	± .028	3	14.999	± .032	2	„ 24	30.277	± .043	15.138	± .021	.279
„ 25	15.351	± .015	2	15.009	± .015	2	„ 25	30.360	± .021	15.180	± .011	.342
„ 27	15.351	± .031	1	15.007	± .015	4	„ 27	30.358	± .034	15.179	± 017.	.344
„ 28	15.384	± .055	1	14.982	± .088	1	„ 28	30.366	± .047	15.188	± .024	.402
Mean							Mean			1.39.15.159	± .008	.366

Note. — Telegraph repeaters were used at Buffalo and Chicago.

Length of telegraph wire in circuit between Cambridge and Buffalo = 504 miles.

„ „ „ „ „ Buffalo and Chicago = 540 „

„ „ „ „ Chicago and Omaha = 498 „

LONGITUDE BETWEEN CAMBRIDGE AND SALT LAKE CITY.

(Not corrected for personal equation.)

Date. 1869.	$\lambda - x_2$	Probable Error.	No. of Series of Signals.	$\lambda - x_1$	Probable Error.	No. of Series of Signals.	Date. 1869.	2λ	Probable Error.	λ	Probable Error.	$x_1 + x_2$ Double Transmission Time.
	h. m. s.			*h. m. s.*				*h. m. s.*		*h. m. s.*		*s.*
Feb. 17	2.43.4.497	±.042	1	2.43.3.966	±.030	2	Feb. 17	5.26.8.463	±.052	2.43.4.232	±.026	.531
„ 18	4.609	±.025	2	3.986	±.025	2	„ 18	8.595	±.035	4.297	±.018	.623
„ 19	4.576	±.022	—	3.985	±.012	3	„ 19	8.561	±.025	4.280	±.018	—
„ 24	4.487	±.035	1	3.982	±.033	2	„ 24	8.469	±.048	4.235	±.024	.505
„ 25	4.596	±.029	2	3.989	±.028	2	„ 25	8.585	±.040	4.293	±.020	.607
„ 27	4.563	±.030	2	3.908	±.035	3	„ 27	8.471	±.046	4.236	±.023	.655
„ 28	4.501	±.041	1	3.827	±.029	2	„ 28	8.328	±.050	4.164	±.025	.674
Mar. 3	4.588	±.054	1	4.048	±.040	2	Mar. 3	8.636	±.067	4.318	±.034	.540
Mean.							Mean.			2.43.4.257	±.008	.591

Note. — Telegraph repeaters were used at Buffalo, Chicago, Omaha, and Cheyenne.
The length of telegraph wire in the circuit between Cambridge and Salt Lake City was 2,583 miles.

LONGITUDE BETWEEN CAMBRIDGE AND SAN FRANCISCO.

(*Not corrected for personal equation.*)

Date. 1869.	$\lambda + x_2$	Probable Error.	No. of Series of Signals.	$\lambda - x_1$	Probable Error.	No. of Series of Signal.	Date. 1869.	2λ	Probable Error.	λ	Probable Error.	$x_1 + x_2$ Double Transmission Time.
	h. m. s.			*h. m. s.*				*h. m. s.*		*h. m. s.*		*s.*
Feb. 17	3.25.7.706	± .020	2	3.25.6.917	± .020	2	Feb. 17	6.50.14.623	± .028	3.25.7.811	± .014	0.789
„ 18	7.715	± .018	4	6.834	± .031	1	„ 18	14.549	± .036	7.275	± .018	.881
„ 24	7.629	± .027	2	6.843	± .038	1	„ 24	14.472	± .047	7.236	± .023	.786
„ 25	7.718	± .024	1	6.865	± .024	1	„ 25	14.583	± .034	7.292	± .017	.853
„ 27	7.728	± .035	1	6.907	± .023	2	„ 27	14.635	± .042	7.317	± .021	.821
„ 28	7.615	± .027	2	6.693	± .034	1	„ 28	14.808	± .044	7.154	± .022	.922
Mar. 3	7.635	± .042	1	6.859	± .047	1	Mar. 3	14.494	± .064	7.247	± .032	.776
„ 5	7.688	± .029	1	6.823	± .029	1	„ 5	14.456	± .042	7.288	± .021	.810
„ 7	7.637	± .022	2	6.923	± .028	1	„ 7	14.560	± .036	7.280	± .018	0.714
Mean.							Mean.			3.25.7.260	± .007	0.817

Note. — Telegraph repeaters were used at Buffalo, Chicago, Omaha, Cheyenne, Salt Lake City, and Virginia City. The length of telegraph wire in the circuit between Cambridge and San Francisco was about 3,580 miles.

LONGITUDE DETERMINATIONS ACROSS THE CONTINENT.

JANUARY AND FEBRUARY, 1869.

(*Final Results.*)

Personal Equations.		*s.*	
Dean — Mosman . . .	= +	0. 11	From Gould's Report of May, 1867, page 75.
Goodfellow — Dean . . .	= +	0. 02	
Dean — Davidson . . .	= +	0.180	From Observations made at San Francisco, April, 1869.

Station.	*Observer.*	*s. Dean's Standard.*	
Cambridge . .	Mosman . .	+ 0.110	To be applied to the Clock Corrections of the respective Stations, to reduce them to Dean's standard.
Omaha . . .	Goodfellow .	— 0.020	
Salt Lake . .	Dean . . .	0.000	
San Francisco .	Davidson .	+ 0.180	

To correct the difference of longitude for Personal Equations, we have :—

		s
Cambridge Time	— Omaha Time	= + 0.130
„ „	— Salt Lake „	= + 0.110
Omaha „	— „ „	= — 0.020
Cambridge „	— San Francisco	= — 0.070
Omaha „	— „	= — 0.200
Salt Lake „	— „	= — 0.180

STATIONS.	Difference of Longitude. (λ)	Personal Equation.	Corrected Difference of Longitude.	Double Transmission Time. $x_1 + x_2$
	h. m. s.	*s.*	*h. m. s.* *s.*	*s.*
Cambridge to Omaha . .	1. 39. 15.159	+ .130	1.39.15.289 ± .008	.336 ± .015
„ „ Salt Lake .	2. 43. 4.257	+ .110	2.43. 4.367 ± .008	.591 ± .019
Omaha „ „ .	1. 3. 49.081	— .020	1. 3.49.061 ± .008	.260 ± .016
Cambridge „ San Francisco	3. 25. 7.260	— .070	3.25. 7.190 ± .007	.817 ± .014
Omaha „ „ .	1. 45. 52.094	— .200	1.45.51.894 ± .010	.483 ± .023
Salt Lake „ „ .	0. 42. 3.026	— .180	0.42. 2.844 ± .008	.242 ± .016

STATIONS.	Difference of Longitude.	$x_1 + x_2$
	h. m. s. s.	s.
Cambridge to Omaha	1.39.15.289 ± .008	.336 ± .015
Omaha to Salt Lake	1. 3.49.061 ± .008	.260 ± .016
Cambridge to Salt Lake (Sum.) .	2.43. 4.350 ± .011	.596 ± .022
Cambridge to Salt Lake (Direct).	2.43. 4.367 ± .008	.591 ± .019
Difference	.017 ± .014	.005 ± .029
Cambridge to Omaha	1.39.15.289 ± .008	.336 ± .015
Omaha to Salt Lake	1. 3.49.061 ± .008	.260 ± .016
Salt Lake to San Francisco . . .	0.42. 2.844 ± .008	.242 ± .016
Cambridge to San Francisco (Sum.)	3.25. 7.194 ± .014	.838 ± .027
Cambridge to San Francisco (Direct)	3.25. 7.190 ± .007	.817 ± .014
Difference	.004 ± .016	.021 ± .030
Omaha to Salt Lake	1. 3.49.061 ± .008	.260 ± .016
Salt Lake to San Francisco . .	0.42. 2.844 ± .008	.242 ± .016
Omaha to San Francisco (Sum.) .	1.45.51.905 ± .011	.502 ± .023
Omaha to San Francisco (Direct).	1.45.51.894 ± .010	.483 ± .023
Difference	.011 ± .015	.019 ± .032
Cambridge to Omaha	1.39.15.289 ± .008	.336 ± .015
Omaha to San Francisco . . .	1.45.51.894 ± .010	.483 ± .023
Cambridge to San Francisco (Sum.)	3.25. 7.183 ± .013	.819 ± .027
Cambridge to San Francisco (Direct)	3.25. 7.190 ± .007	.817 ± .014
Difference	.007 ± .015	.002 ± .030
Cambridge to Salt Lake	2.43. 4.367 ± .008	.591 ± .019
Salt Lake to San Francisco . . .	0.42. 2.844 ± .008	.242 ± .016
Cambridge to San Francisco (Sum.)	3.25. 7.211 ± .011	.833 ± .025
Cambridge to San Francisco (Direct)	3.25. 7.190 ± .007	.817 ± .014
Difference	.021 ± .013	.016 ± .029
Cambridge to San Francisco . .	3.25. 7.190 ± .007	.817 ± .014
(C. to O.) + (O. to S.L.) + (S.L. to S.F.)	7.194 ± .014	.838 ± .027
(C. to O.) + (O. to S.F.)	7.183 ± .013	.819 ± .027
(C. to S.L.) + (S.L. to S.F.) . . .	7.211 ± .011	.833 ± .025
Cambridge to San Francisco Mean of all	h. m. s. s. 3.25. 7.194 ± .006	s. .827 ± .012

6. On the Use of the Zenith Telescope for Observations of Time. By J. E. Hilgard, of Washington, D.C.

The Zenith Telescope, or equal altitude instrument, has now during twenty years been used very successfully for determinations of latitude, and, with Americans, has become the favorite field-instrument, both on account of the precision of its results, and of the facility of observation. Its power for the determination of time has not, however, been developed, although well adapted for the purpose. Gauss, indeed, has shown long since how observations of stars on the same horizontal circle, or at equal altitudes in different verticals, would yield the co-ordinates of time and latitude, and has solved the problem in its most general form. But the want of a sufficient number of well-determined stars prevented him from developing the most advantageous special cases of the method, requiring the minimum of computation; viz., the determination of latitude by equal altitudes on the meridian, north and south of the zenith, and that of time, by equal altitudes on its prime vertical, east and west of the zenith.

When we consider the great precision with which the Zenith Telescope enables us to observe *equal altitudes*, we will perceive at once its applicability to that purpose. Here, as in the observations for latitude, we require a number of well-determined stars grouped according to certain conditions. The abundance of such positions that is afforded by recent catalogues of stars renders of easy application methods which would formerly have failed for want of such data, and which for that reason were not developed.

If two stars of precisely the same polar distance, but differing some hours in right ascension, had been observed at the same zenith distance on opposite sides of the meridian, one to the east, the other to the west, it is obvious that the mean of their right ascensions would express the right ascension of the zenith, or the sidereal time corresponding to the mean of the observed times. Further, if there were but a small difference in polar distance, the corresponding change in the hour-angle, or correction to the time, could be expressed by a simple differential formula.

Since the determination of time by means of zenith distance is most advantageous when the star is on the prime vertical, we will first consider the proposed method under that condition, which,

moreover, affords the practical convenience that an opening along the east and west line of the observatory, if the instrument is housed, will afford the command of all the stars that may be selected. In the temporary observatories used in the Coast Survey, the ridge of the roof runs east and west; and it is very easy so to construct it, with a double ridge-beam, as to have an opening of six inches, which will be covered by a folding door.

We propose, then, to select a pair of stars so conditioned that they will pass the prime vertical at nearly equal zenith distances on opposite sides of the meridian, at no great interval of time from each other. This requires that their polar distance should be nearly equal; moreover, the stars must be south of the zenith, in order that they may pass the prime vertical at all, and yet sufficiently far north of the equator, in order that they may cross the prime vertical at an altitude beyond the influence of irregular refraction. This somewhat limits our selection. Before defining the limits more precisely, we will now consider the formulæ required for computation.

We require to know, approximately, the hour-angle, H, and the zenith distance, ζ, for the purpose of making the selection and preparing for the observations. We have given the co-latitude λ, the polar distance Δ, and the right angles at the zenith.

We have for the hour-angle —

$$\cos H = \cot \Delta \tan \lambda;$$

for the zenith distance —

$$\cos \zeta = \cos \Delta \sec \lambda.$$

We further require differential expressions for the variations in the hour-angle, arising from a change in polar distance, and from that change in zenith distance which is expressed by the level correction. As the zenith distance gives the most convenient expressions, and is also required for setting the instrument, we employ it for that purpose, and obtain readily —

$$dH = d\Delta \frac{\tan \lambda}{\sin \Delta \sin \zeta} \qquad dH = d\zeta \frac{\cos \zeta}{\cos \Delta \tan \lambda}$$

As we have in the first expression the sine of the zenith distance as a dividend, we are warned not to come too near the zenith in this method of observing for time, lest the error in the difference of polar distance be greatly exaggerated in the correction of the time.

Assuming the uncertainty of that difference at one second of arc, we must not allow the numerical value of the factor —

$$\frac{\tan \lambda}{\sin \Delta \sin \zeta}$$

to exceed three, if we would not admit an uncertainty greater than two-tenths of a second of time. Hence we should not choose stars that cross the prime vertical nearer to the zenith than about 30°.

The problem would take a more favorable form in this respect if we could observe the stars precisely on the prime vertical, and measure with the micrometer the difference of zenith distance due to that of polar distance. But, as we have no means of fixing the instrument in that vertical, it is best to accept the simpler mode of using equal altitudes. We shall, however, hereafter consider more fully the mode of observing just mentioned.

Let us now illustrate the proposed method by an example. Wishing to make observations for time in that way at Washington, in October, 1869, we proceed as follows: —

Taking the latitude at 38° 53′ 40″, and adopting 75° as the greatest polar distance to be used, in order not to approach too near the horizon, we prepare for the selection of stars by computing a table of zenith distances and hour-angles, as given below. This may be done by computing for every second degree, and interpolating the intermediate values. This is the only part of the operation that may appear laborious to observers; but as the factors *tan* λ and *sec* λ are constant, the computation can be made very readily. Arresting the computation when a zenith distance of about 30° is reached, we form the following table: —

ZENITH DISTANCE AND HOUR-ANGLE OF STARS ON THE PRIME VERTICAL, FOR LATITUDE OF WASHINGTON, 38° 53′ 40″.

Δ	ζ	H in arc.	H in time.
			h. m. s.
75°	65° 39′.4	70° 36′.0	4 42 24
74	63 57.6	69 10.8	4 36 43
73	62 14.9	67 43.8	4 30 55
72	60 31.1	66 14.9	4 25 00
71	58 46.0	64 44.1	4 18 56
70	56 59.7	63 10.9	4 12 43
69	55 11.8	61 35.2	4 06 21
68	53 22.3	59 56.7	3 59 47
67	51 30.9	58 15.2	3 53 01
66	49 37.5	56 30.2	3 46 01
65	47 41.7	54 41.3	3 38 45
64	45 43.2	52 48.1	3 31 12
63	43 41.5	50 49.9	3 23 20
62	41 36.5	48 46.2	3 15 05
61	39 27.2	46 35.9	3 06 24
60	37 13.2	44 18.1	2 57 13
59	34 53.2	41 51.5	2 47 26
58	32 26.2	39 14.0	2 36 56
57	29 50.3	36 23.5	2 25 34

Determining next the sidereal hour at which it is proposed to commence observations, we make our selection from the British Association's Catalogue of Stars, by choosing a well-determined star of suitable polar distance, having a right-ascension less than the proposed sidereal time by the approximate hour-angle, and then looking for a mate of nearly the same polar distance in a right-ascension greater by twice the hour-angle; the former being the western, the latter the eastern star of the pair.

The following table, giving a selection of eligible pairs from a much larger number yielded by the Catalogue, will show that there is an abundant choice: —

TABLE OF SELECTED PAIRS.

	Star B.A.C.	α	Δ	H.	Sid. Time when on Prime Vertical.	ζ Approx.
		h. m.		h. m.	h. m.	
W.	481	1 19	71° 26′	4 21	20 58	59° 28′
E.	5702	16 49	71 21		21 10	
W.	707	2 10	70 42	4 17	21 53	58 14
E.	6080	17 43	70 42		22 00	
W.	1390	4 22	71 39	4 23	28 59	60 00
E.	6788	19 41	71 46		0 04	
W.	1376	4 20	71 06	4 20	0 00	59 00
E.	6794	19 43	71 10		0 03	
W.	1934	5 55	70 18	4 14	1 41	57 32
E.	7528	21 33	70 20		1 47	
E.	5900	17 20	69 49	4 12	21 32	56 40
W.	577	1 47	69 50		21 35	
W.	556	1 42	68 22	4 02	21 40	54 06
E.	6106	17 56	68 24		21 58	
W.	644	1 59	68 00	4 00	21 59	53 26
E.	6231	18 15	68 05		22 15	
E.	6387	18 40	69 35	4 10	22 50	56 22
W.	1045	3 15	69 43		23 05	
E.	7275	20 52	68 10	4 01	0 53	53 32
W.	1637	5 11	68 01		1 10	
E.	6116	17 57	67 04	3 58	21 50	51 37
W.	581	1 48	67 03		21 55	
E.	6827	19 48	66 15	3 48	23 36	50 08
W.	1147	3 37	66 18		23 49	
E.	6835	19 49	66 01	3 46	23 35	49 38
W.	1095	3 26	65 58		23 40	
W.	1107	3 29	67 18	3 55	23 34	51 57
E.	6866	19 53	67 15		23 48	

TABLE OF SELECTED PAIRS,—*continued.*

	Star B.A.C.	x h. m.	Δ ° ′	H. h. m.	Sid. Time when on Prime Vertical. h. m.	ζ Approx. ° ′
W.	1527	4 49	66 15	3 48	1 01	50 08
E.	7437	21 18	66 17		1 06	
E.	7585	21 40	67 39	3 57	1 37	52 40
W.	1915	5 32	67 36		1 56	
W.	796	2 29	65 55	3 46	22 43	49 30
E.	6542	19 00	65 57		22 46	
E.	6676	19 28	63 30	3 27	22 50	44 42
W.	813	2 21	63 30		23 05	
E.	6940	20 05	63 32	3 28	23 33	44 49
W.	980	3 02	63 35		23 34	
E.	7461	21 21	62 57	3 23	0 45	43 36
W.	1526	4 12	62 57		0 49	
W.	1803	5 45	62 25	3 19	2 26	42 32
E.	8097	23 09	62 28		2 28	
E.	6648	19 19	60 38	3 08	22 22	38 35
W.	514	1 34	60 36		22 31	
W.	8206	23 27	59 23	2 51	20 36	35 50
E.	6147	18 02	59 27		20 53	

From this table the observer would arrange his scheme of work to suit the other observations he had in hand. For the purpose of determining the correction of the chronometer for observations of latitude or azimuth, he would content himself with observing three or four pairs in an evening; and, in order to select these, he would not be under the necessity of forming so extensive a table as above given, but could readily find from the Catalogue suitable pairs for the special times at which he wished to make the determinations of time.

The following may serve as an example of an observation:—

Example of Observation.

Washington, *October* 15, 1869.— The passages of the star are observed over the fixed horizontal wires marking the micrometer readings 10, 20, 30, and over the micrometer-wire set at 15 and 25 turns. Instrument set to zenith distance 42° 33′. One division of level = 1″.

The observations are made near the middle vertical wire, the instrument following the star in azimuth by means of the tangent screw.

Star.		Micr.	Chron. Time.			Level.	
			h.	*m.*	*s.*	*E.*	*W.*
1863	*W.*	30		26	44 .0	26.5	28.0
(136 Tauri) . . .		25		27	04 .3		
		20	2	27	24 .5		
		15		27	44 .8		
		10		28	05 .0		
		Mean	2	27	24.52		
8097	*E.*	10		28	33 .1		
(61 Pegasi) . . .		15		28	53 .5		
		20	2	29	13 .7		
		25		29	34 .0		
		30		29	54 .2	30.0	24.5
		Mean	2	29	13.70	56.5	52.5

Computation.

		h.	*m.*	*s.*				
8097	*A.R.*	23	09	25.28	Δ	62°	27′	34″.6
1863		5	45	08.21		62	25	24 .0
Mean of *A.R.*		2	27	16.74	*dΔ*		2	10 .6 = 130″.6

Arranging the signs for the form *E.* — *W.*, we observe that the star having the greater polar distance has also the greater hour-angle; and that if the eastern star have the greater polar distance, making *E.* — *W.* positive, it will cross the prime vertical earlier: therefore, in order to make the observation what it would have been if both stars had the same polar distance, we must add the correction for difference of polar distance —

$$dH = \frac{d\Delta}{15} \frac{tan\,\lambda}{sin\,\Delta\,sin\,\zeta} = 18^{s}.01$$

to the sum of the observed times, or half of it to their mean, with the sign resulting from taking the polar distance of the western from that of the eastern star.

Again, as to the level correction, if the east end is too high, the zenith of the instrument is to the west of the true zenith, and the observation will be too late by a corresponding amount. The level correction must therefore be applied with the sign resulting from subtracting the east readings from the west readings. The scale being numbered each way from the middle, we must take one-fourth the difference of the sum, and find the level correction to be — 1″, which, multiplied with $\frac{\cos \zeta}{15 \cos \Delta \tan \lambda}$, gives $-0^{s}.086$ as the corresponding correction to the observed time. We have therefore: —

	h.	m.	s.
Mean of observed time	2	28	19.11
Correction for $d\Delta$			+09.00
Correction for level			— 0.08
Corrected Mean of observed times . .	2	28	28.03
Mean of right ascensions	2	27	16.74
Chronometer fast		1	11.29

The restriction to observation of equal altitudes near the prime vertical was adopted, at the outset, from considerations of the more ready computation of the hour-angle and zenith distance in the right-angled triangle, and of the convenience of having a continuous opening in the field-observatory along the ridge of the building. Moreover, the determination of time by equal altitudes is most exact when made in the prime vertical.

It may nevertheless prove expedient to choose pairs of stars not so situated, especially such as can be found in the astronomical ephemeris, with the apparent places ready to hand. Of such pairs, a larger number than might be anticipated may be found, having nearly equal polar distances, and sufficiently far apart in right ascension to yield good determinations of time. The following list has been selected from the American ephemeris: —

Selected List of Pairs.

Star.	Right Ascension.	Declination *N.*
	h. *m.* *s.*	° ′ ″
α Androm.	0 01 37	28 22 02
β Tauri	5 18 01	28 29 37
Mean	2 39 49	Diff. 7 35
θ Piscium	23 21 19	5 39 34
α Can. Min.	7 32 26	5 33 30
	8 26 53	6 04
α Androm.	0 01 37	28 22 02
β Gemin.	7 37 17	28 20 24
	3 49 27	1 38
ζ Arietis	3 07 22	20 33 26
γ Leonis	10 12 44	20 30 10
	6 40 03	3 16
β Leonis	11 42 22	15 18 16
γ Tauri	4 12 20	15 18 31
	7 57 21	15
ε Tauri	4 20 58	18 53 14
η Bootis	13 48 26	19 03 19
	9 04 42	10 05
φ Gemin.	7 45 28	27 06 07
α Cor. Bor.	15 29 08	27 09 27
	11 37 18	3 20
ε Hydræ	8 39 50	6 53 51
α Serpentis	15 37 48	6 50 23
	12 08 49	3 28
α Leonis	10 01 24	12 36 23
α Ophiuchi	17 28 51	12 39 28
	13 45 07	3 05

SELECTED LIST OF PAIRS,—*continued.*

Star.	Right Ascension.			Declination *N.*		
	h.	*m.*	*s.*			
12 Can. Ven..	12	49	53	39°	01′	35″
η Herculis.	16	38	24	39	10	23
Mean.	14	44	08	Diff.	8	48
η Boötis	13	48	26	19	03	19
1 Pegasi	21	16	02	19	14	44
	17	32	14		11	25
α Herculis.	17	08	40	14	32	31
α Pegasi	22	58	14	14	30	04
	20	08	27		2	27
α Herculis.	17	08	40	14	32	31
γ Pegasi	24	06	30	14	27	19
	20	37	35		5	12
o Piscium	1	38	29	8	29	50
α Aquilæ	19	44	23	8	31	28
	22	41	26		1	38

If we are observing in the open air, a selection from these pairs will be found the most convenient, requiring very little preparation. In a temporary observatory, it may be found best to make small openings, with covers, for those stars that are selected to serve for the determination of time on a series of nights.

To illustrate the method we take the following pair:—

		h.	*m.*	*s.*				
α Andromedæ	*A.R.*	0	01	37	*N.P.D.*	61°	37′	58″
β Geminorum		7	37	17		61	39	36

The observation is to be made at the sidereal time expressed by the mean of the two right ascensions, or about $3h.\ 49m.\ 27s.$ But it concerns us to have a convenient interval between the two observations, and we must choose the zenith distance somewhat greater, in order to observe the eastern star earlier and the western

star later. Taking, therefore, the hour-angle about two minutes longer, or at $3h.\ 50m.$ or 57° 30′, and the mean polar distance 61° 38′.8, we compute the approximate zenith distance to be 48° 13′.6 by the formulæ,—

$$\tan M = \tan \lambda \cos H, \qquad \cos \zeta = \cos \lambda \sec M \cos (\Delta - M).$$

In setting to this zenith distance, we neglect the refraction, which has the effect of slightly increasing the interval between the two stars reaching the middle wire.

Assuming the observed times to have been —

	h.	m.	s.
E.	8	48	28.3
W.	8	52	47.2
Mean. .	8	50	35.25

we compute the correction for difference of polar distance by the differential expression —

$$dH = \frac{d\Delta}{30}\left(\frac{\cot \lambda}{\sin H} - \frac{\cot \Delta}{\tan H}\right)$$

dividing $d\Delta$ by 2×15 in order to convert it into time, and apply the half of it to the mean of the observed times; the sign *E.* — *W.* holding good as before.

$d\Delta$ being + 98″, we find $dH = +\ 2^{s}.00$.

Furthermore, the level readings indicating the west end high 1″.5, we must add to the observed times —

$$dH = \frac{d\zeta}{15} \cdot \frac{\sin \zeta}{\sin \lambda \sin \Delta \sin H} = +\ 0''.13;$$

and we have therefore —

	h.	m.	s.
Mean of observed times.	8	50	35.25
Correction for $d\Delta$			+ 2.00
Correction for level			+ 0.13
Corrected time by chronometer . . .	8	50	37.38
Mean *A.R.* or sidereal time	8	49	27.00
Chronometer fast.		1	10.38

The simplest and most direct mode of determining the time from equal altitudes is that of observing the *same star* on or near the prime vertical, on both sides of the zenith. In order that the observation may be confined within convenient limits of time, the

star should have a small zenith distance, or its declination must be nearly equal to the latitude of the station. The limit of zenith distance corresponding to any assumed limit of interval between the eastern and western observation can be readily computed; but it will practically suffice to say, for our latitudes, that the zenith distance should not exceed one degree.

That the star should pass to the south of the zenith is most advantageous; but, even if it passes to the north within that limit, the observation will be quite satisfactory, although, of course it cannot be made on the prime vertical. The preparation for the work will be the same as already set forth; and, as the observations are presumed to be made at precisely equal altitudes, the mean of the observed times corrected for level error will correspond to the right ascension of the star.

It is worthy of note that both time and latitude may be determined with the zenith telescope, by observation upon one star passing within a few minutes of the zenith, in the following elegant manner. The instrument being set to the zenith, turn it in azimuth to the east, and note the passage of the star over a wire rather low in the field: next turn to the south, point the micrometer on it about twenty seconds before the meridian passage, read, turn the instrument to the north, and again bisect the star about twenty seconds after meridian passage, and finally note the passage over the same wire as before, as the star descends to the west. The mean of the east and west observation will give the time of the star's meridian passage; while the difference of the north and south observation will give twice the zenith distance on the meridian, in turns of the micrometer. The level may be read in the several positions, before or after the observations on the star.

We have referred to the plan of making the observation for time by measuring the difference of zenith distance in the prime vertical with the micrometer, when using two stars of unequal declination.

The general scheme would be to correct the difference of time by means of the measured difference of zenith distance, and thus reduce the observation to the case of equal altitudes of stars having the same declination. But the details of the observation, as well as of the reduction, would be much more complicated than in the cases that we have developed; and since no lack of stars suitable for those methods is to be apprehended, it would not be useful to explain more fully the plan last mentioned.

The foregoing method has been sketched chiefly with the view of setting forth that the transportation and mounting of a transit instrument may be dispensed with, when the determination of the time is only required for the purpose of reducing latitude observations made with the zenith telescope; and those of the azimuth of geodesic lines, which are usually combined with the former. When the latter only are required, the theodolite itself will serve conveniently for the determination of time, used either as a transit, or for equal altitudes, in the manner above described.

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7. The Four Great Eras of Modern Astronomy. By Jacob Ennis, of Philadelphia, Penn.

A knowledge of the four great eras of Modern Astronomy is of practical value, to direct the course of astronomical labor. These four eras were made by the discoveries of Copernicus, of Newton, of Laplace, and of the present time.

Nothing in astronomy can be more plain than that the discovery by Copernicus of the real movements of the solar system is a great era, although it did not appear such to his contemporaries, or to the next two generations. That discovery is the very basis of all just ideas in astronomy, the foundation of our conceptions of the constitution of the universe.

It is now, also, equally as plain that the discovery by Laplace of the origin of the movements of the solar system is just as great as the discovery of the movements themselves. To know how the planets and satellites move in their intricate and mazy orbits is not more wonderful than to know how those strange movements and orbits received their origin. To understand the constitution of the solar system is a grand achievement of the human mind, but to understand how that constitution came into being is equally as grand. Therefore the theories of Copernicus and Laplace must stand side by side, equal in importance, and equal in their influence, to direct all succeeding astronomical investigations.

The theory of Copernicus, however, was defective: it was a noble beginning, but needed development. While it revealed the

true motions of the planets and satellites in their orbits, it revealed no *force* to retain them in those orbits. What prevented them from flying off far away from those orbits by centrifugal force, like a stone from a sling? Here we come to the grand era of Newton. He discovered the force which retains the celestial bodies in their orbits, a force pervading the infinity of space, and opening to our minds new and truly sublime visions of the universe.

The theory of Laplace was defective in the same manner as that of Copernicus. It revealed the *mode* by which the solar system had been formed, but it knew nothing of the *force* by which that method had been carried on. It saw the manner in which the system of movements of the planets and satellites had been produced, but it saw no power by which that system had originated. Here we come to the last of the four great eras. It is the discovery of FORCE which produced nebular rotation, which arranged the planets and satellites in their orbits, and which gave origin to all the sublime evolutions and revolutions of the stars. It makes clear the origin of all the vast sidereal systems, in which an entire solar system is but an atom.

The four eras stand related to one another in this way. Copernicus discovered the true motions of the stars in their orbits. Laplace discovered how these motions of the stars might have been produced. Newton discovered the *force* which now holds the stars in their orbits. The fourth era has discovered the *force* which, in the beginning, put all the stars in motion in their orbits.

All these eras, as they have occurred at long intervals from one another, have each one laid the foundation for new classes of truths, and have opened new and peculiar fields of discoveries. Kepler's three laws were but additions to the system of Copernicus. The same system was farther enlarged by the discoveries of the four satellites of Jupiter, and of the phases of Venus, by Galileo. The discoveries of Uranus and Neptune, of the rings of Saturn, of the numerous satellites, of the more numerous asteroids, of comets revolving in regular orbits around the sun, and of meteors which seem to be comets revolving in similar orbits, — all these are simply the filling up of the outlines of Copernicus.

The same is true of the era of Newton. When he had discovered that the force of gravity held the planets and satellites in their orbits, he found that he had opened a wide field for the discovery of a large class of similar truths. The three laws of Kepler, the precession of the equinoxes, the irregularities in the

motions of the moon, and various planetary phenomena, he found to be merely the consequences of the force of gravity. These interstellar influences of gravity, nobly pursued by Newton, have been further followed out by Euler, Biot, Delambre, Lagrange, Laplace, Leverrier, Adams, Hansten, Dulaunay, and others. All these, by studying merely the influence of gravity, have accumulated a noble fabric of truth, culminating in the discovery of Neptune, and in unravelling the strange vagaries of the lunar theory. But the greatest of all the services performed by the study of the influences of gravity, as the centripetal force, is the absolute proof which that study affords of the truth of the Copernican theory.

The era of Laplace, formed by his nebular theory, has, like those of Copernicus and Newton, opened a wide field of discoveries, a field peculiarly its own. Here we learn how the stars have been created, and how they have been arranged in solar and sidereal systems. It has often been repeated, even by a frequent writer on the nebular theory, that he founded his theory on the discoveries of the elder Herschel among the nebulæ. Herschel believed that some insoluble nebulæ were great gaseous bodies condensing into stars. But the idea of the formation of stars from the condensation of diffused nebulous matter seems to be as old as astronomy itself. It was held by Kant, it was discussed by Newton and others in his day, and it was a favorite theme of Lucretius, and other ancient Greeks and Romans. But the peculiarity of the theory of Laplace is the formation of planets and satellites moving in their intricate orbits around the sun. No one, before Laplace, had speculated on the origin of the peculiarities of the solar system, except Buffon; and his speculations were far different, and plainly untenable. To Laplace, therefore, alone belongs the great merit of forming the nebular theory. But as it came from his hands it aspired to nothing further than simply to account for the great and leading peculiarities of our own solar system. He pointed out the origin of the planets and the satellites, and the *mode* in which they had received their motions; but he said nothing of the origin of the sun, or the fixed stars, or the comets, or the *force* which arranged all solar and all sidereal systems, and gave all the heavens and the earth their motions. The history of the nebular theory shows that it has gone through three very different stages of growth, preserving meanwhile its first fundamental principles. These stages were as follows: —

The first stage was that delineated by Laplace. He assumed

the existence of all the fixed stars, and of the sun rotating on his axis just as now. Then a time arrived when, from some extraordinary but unknown cause, the heat and light of the sun were increased, like the temporary star of 1572, which suddenly appeared and blazed up with unwonted effulgence. By this increased heat the atmosphere of the sun was expanded to beyond the orbit of the farthest planet. Comets of short periods, Laplace believed, had previously revolved around the sun, as well as those of long periods; but by this enlargement of the solar atmosphere all the comets of short periods had been absorbed, as well as those of long periods which came at that time within the enlarged solar atmosphere. As the extraordinary fires of the sun died out, like the star of 1572, the solar atmosphere then contracted; and, as it preserved all the while the original rotation of the sun, it abandoned, by centrifugal force, equatorial rings, which broke, subsided into nebular planets, which, by cooling and condensing and rotating, in like manner abandoned other rings. These latter rings broke, and formed nebular satellites; all these nebular bodies ultimately condensing into solid stars. The rings of Saturn he regarded as formed by the same process, but, from some cause unknown to him, they remain unbroken. It is proper here to mention the wonderful sagacity of Laplace in foreseeing the existence of comets of short periods long before their actual discovery, and for which, until to-day, he has not received a word of credit. This acknowledgment, therefore, is so much the more appropriate now. His foresight arose, doubtless, in this instance at least, from his familiarity in applying the doctrine of probabilities. His mistake was in supposing all the comets of short periods to have been destroyed by the enlarged solar atmosphere.

The second stage of the nebular theory went back to a period anterior to that contemplated by Laplace. It attempted to account for the condensation of the sun and the fixed stars from a former nebulous state. It began with large, round, nebulous bodies, vastly expanded by heat. "Fire mist" was the term often used to express their condition. Some writers, as Helmholtz, assumed these bodies as already in a state of rotation. Others, as Nichol and Trowbridge, and the author of the "Vestiges of Creation," sought to find conditions causing rotation in their cooling and contraction, and in the meeting of their materials at the centre. These several nebulous globes, by condensation, were regarded as forming fixed stars, and solar and sidereal systems.

There were conspicuous difficulties in the nebular theory, in both the first and second stages of its progress. Laplace did not attempt to account for the rotation of the sun with its expanded atmosphere from which the planets were derived, and hence he did not pretend to a knowledge of the force which originally gave motion to the planets and satellites. In the second stage of the nebular theory, the first great difficulty was to find an adequate cause for the rotation of the nebulous globes. The second difficulty was to calculate from time to time the velocity of nebular rotation, and to learn whether that velocity coincided with the velocities of the several planets and satellites. The third difficulty was to show that nebular rotation could become so rapid that the centrifugal force should equal the centripetal force, and thus abandon equatorial nebulous rings. None of these difficulties were overcome by Laplace and his followers, under either the first or second stages of nebular progress. Still another difficulty was the intense fiery condition of the round, nebulous bodies. That could not have been a permanent condition; because, from what we know of the extreme coldness of the general regions of space, the heat must speedily have radiated away. Immediately anterior to this point of time when contraction and rotation were to begin, there must have been in operation some great and extraordinary cause producing all this heat; and such a cause, so far from being probable, cannot even be conceived.

Still, notwithstanding all these difficulties, arising chiefly from the want of mathematical proof, Laplace, in forming his nebular theory, achieved one of the grandest of all sublime conceptions. He showed how that theory coincided with the great leading features of the solar system: the orbits of the planets nearly circular, their positions nearly in the plane of the sun's equator, their revolutions from west to east like the rotation of the sun, the corresponding relations of the satellites to the planets, the preservation unbroken of some of the rings of Saturn, and the rotations of the sun, the planets, the satellites and the rings of Saturn in the same direction. The doctrine of probabilities demonstrated that so many movements in the same direction must have arisen from a common cause, and his theory pointed to a common cause. These coincidences between the facts of the solar system, and his sublime theory of the origination of that system, have always been strong proofs in its favor.

But the progress of the development of this theory, from the

time of its publication in 1796, during seventy years, to 1866, was exceedingly slow. A distinguished writer on the nebular theory lately remarked that "very little had been accomplished since the time of Laplace tending either to invalidate or to confirm it." Still its development was not so slow as that of the Copernican theory during its first seventy years, and not slower than the Newtonian theory during an equal period. But not much progress in the development of the nebular theory could be expected when the very force which caused the nebular rotation was unknown. Consequently it was then impossible to give mathematical proof that the velocity of nebular rotation could equal that of the planets in their orbits, or could be rapid enough to abandon by centrifugal force nebulous rings from the equatorial zone. In order to go on with its developments, evidently the nebular theory was awaiting the discovery of the force which caused all its motions.

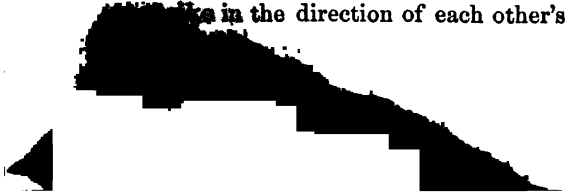
We come now to the fourth era in modern astronomy, — the discovery of the force which imparted all their motions to all the stars. These motions of the stars were received in their nebulous condition, and therefore we must study the nebular theory to find out the cause of nebular and stellar motions.

The sublimest of all contemplations about our earth is its rapid flight. To think that we live on a rotating ball nearly 8,000 miles in diameter is grand enough; but how much more grand to think of this rotating ball flying onward a thousand miles every minute! Its myriads of inhabitants, from insects up to men, quiet and undisturbed, feel not the change. Some of the beautiful stars in the clear blue sky move three times more rapidly. All of them have compound motions, two, three, and four motions combined. The sun has two motions, the planets three, and the satellites four. The latter have a rotation on their axis, a revolution around the planets, a revolution around the sun, and a revolution around the centre of the sun's orbit. How did the Creator impart so many swift and mazy movements? What was the instrument in His hand? That great instrument was the simple force of gravity, — the force which lifts the vapor of the ocean in the air, and brings it down as gentle rain on the meadows. In view of the origin of all these stellar motions, the heavens declare the glory of God, and the firmament His handiwork.

The mode in which gravity was discovered to have originally imparted all their motions to all the stars was through the third and last stage of the nebular theory now to be described. The

first stage, I have said, began with the sun rotating on its axis as in our day, and afterwards its atmosphere was enlarged to beyond the orbit of the farthest planet. The second stage began with large, fiery, nebulous globes, which by cooling condensed into stars. The third and last stage began with all matter nearly evenly diffused through all space. This diffusion was not caused by heat, but it was simply the normal condition of matter in a gaseous form. Its contraction and ultimate condensation and fiery condition were the results of chemical action, the same as oxygen and hydrogen unite and condense, with evolution of heat, into water, occupying nearly 2,000 times less space. The first effect of contraction was the breaking up of the nearly even diffusion of matter into separate huge nebulous clouds, irregular in shape, different in size, and at unequal distances apart. Then by the inter-action through gravity of these nebulous masses on one another, by the process of becoming round, and by their falling into one another obliquely and not in the direction of each other's centres of gravity, rotation must inevitably ensue. In these contracting globes, rotation, having once begun, must be increased by gravity; and, in nearly all cases, the velocity of rotation must become such that nebulous rings must be parted from the equatorial zone. These rings, revolving with great velocities, break and condense into stars *endowed with the very same velocities!*

It is plain that this third stage of the nebular theory was necessary to discover the force which caused nebular rotation, and consequently all stellar motion. The fiery, nebulous globes, which begin the second stage of the nebular theory, had no way to originate rotation. They were regarded as independent, and destitute of inter-action through gravity. Hence such writers as Helmholtz assumed them as already rotating, without reference to any rotating cause. The third stage shows clearly how rotation must originate and gradually increase. It begins with a normal condition of matter, a gaseous diffusion. It assumes a normal cause for contraction, chemical combination. The breaking up of the contracting gases into clouds is another normal state; and these clouds we are bound to suppose similar to clouds in our own day, different in size, irregular in shape, and at unsymmetrical distances from one another. Gravity must cause these clouds to fall into one another until their distances apart become so vast as to be beyond each other's influence. In coming together, no two could [illegible] in the direction of each other's centres, because they would



be under the influence, through gravity, of other neighboring nebulæ. Hence they must strike each other obliquely, and therefore the resulting mass must rotate. Moreover, all clouds have irregular projections; and these also, for the same reason, in falling towards the centre, must fall obliquely, and produce lateral surface currents. These lateral currents, by the composition of forces, must coalesce into one current around the new-born globe, and thus form a surface rotation. This surface rotation must be *retarded* by friction on the unrotating or slowly rotating interior; and this fact of retardation accounts for many of the most important astronomical phenomena. Therefore, in this third stage of the nebular theory, we discover the force which gave origin, first to all nebular rotation, and then, as a consequence, to all stellar motions. It is the same force which arranged and moulded all sidereal and solar systems. Here we unlock the mystery of the mazy dance of planets and satellites, which have three and even four motions at the very same instant.

This discovery of the projectile force in astronomy, like the discovery of the centripetal force by Newton, leads to many other discoveries. The greatest of all the services performed by the discovery of gravity as the centripetal force was the absolute proof it affords of the truth of the Copernican theory. In like manner, the greatest of all the services performed by the discovery of gravity as the centrifugal or projectile force is the absolute proof it affords of the truth of the nebular theory.

We glanced briefly at the new fields of research opened by each of the three former eras in modern astronomy, and we may now take a rapid survey of the new and peculiar field of discovery opened by the fourth.

1. When it was discovered that gravity is the force which put the stars in motion, the fact became evident that both the centripetal and centrifugal forces, although opposite in their directions, are one and the same in their origin. Faraday has observed, with all the simplicity and directness which characterize great genius, that inertia is always a pure case of the conservation of force. The centrifugal force is the force of inertia. It arises from a planet's velocity; and the greater its velocity, the greater its force of inertia. As this velocity is caused by gravity, therefore inertia or the centrifugal force is merely gravity conserved. By this conservation the force of gravity is made to act antagonistic to itself.

2. Gravity was then seen to have been the only force which originally gave all their peculiar arrangements to all stellar systems, whether they be sidereal, solar, or planetary. It determined not only the velocities of the celestial bodies, but the directions of their movements, the sizes and positions of their orbits, and even their separate existences. The direction in which any nebula rotated was determined through gravity by the direction in which one nebula fell into another, or in which the projecting arms of a nebula were brought down to the level of rotundity. The direction of rotation of the nebula determined the planes of the orbits of the planets and satellites, and the direction of their revolutions and rotations. And gravity, by its conversion into the centrifugal force, separated equatorial rings, broke those rings, and moulded them into round rotating bodies. But as gravity is one and the same, the question arises, How could it produce the infinite variety of stellar systems, no two being alike, as no two trees of the forest are alike? This diversity it produces by acting on an infinite diversity of nebulous clouds, no two being alike, as no two clouds in our atmosphere are now alike. The entire work of the creation of suns, and of the many systems of stars, was thus found to have been wonderfully simple. It was the action of gravity on slowly contracting nebulæ, whatever the cause of that contraction may have been. Following out this one mighty creative force in its manifold operations, the following additional discoveries have been made.

3. The reason why Neptune, Uranus, Saturn, and Jupiter, the four outer planets, have all the satellites but one; and why of the four inner planets, Mars, Earth, Venus, and Mercury, the Earth alone has a satellite.

4. The reason why Saturn parted so many more equatorial rings than the other planets, eleven in all, while Jupiter parted only four; the reason why Saturn's outer ring was so distant, more than 2,300,000 miles, while that of Jupiter was less than 1,200,000; and the reason why Saturn's inner ring is so near his surface, only about 12,000 miles, while that of Jupiter is more than 220,000 miles from his surface.

5. All nebulæ, solar and planetary, rotated with constantly *increasing* velocities. Hence each planet and satellite has a greater velocity than its next outer neighbor. But, after the parting of the last equatorial ring, then the sun and also the planets began to rotate with *decreasing* velocities. Therefore the equatorial velocity

of the sun is now less than the orbital velocities of the planets, and the equatorial velocities of the planets are less than the orbital velocities of the inner satellites. The cause of this is found to be the principle of retardation.

6. The reason why retardation was so much greater in the nebulous sun than in the nebulous planets.

7. The reason why each planet and satellite was produced at a less inter-planetary or less inter-satellite distance than its next outer neighbor; and the reason why the last planet Mercury, in the solar system, and the last satellites Mimas and Ariel, in the planetary systems of Saturn and Uranus, are exceptions.

8. The reason why there is no planet interior to Mercury.

9. The reason why the inter-planetary spaces, from 25,000,000 miles to 1,000,000,000 miles, are so much wider than the inter-satellite spaces, which are from 35,000 to 1,000,000 miles.

10. The reason why the sun ceased producing equatorial rings so far from his present surface, 35,000,000 miles, while the planets continued to produce rings, until within the following much shorter distances, — 234,000, 224,000, 200,000, 104,000, and 12,000 miles.

11. The reason why the orbits of the planets and satellites are elliptical.

12. The reason why the orbital planes of the planets are not in the equatorial plane of the sun; why the orbital planes of the satellites are not in the equatorial planes of the planets; why the axes of the planets and satellites are not perpendicular to their orbital planes; and why the rotations of Uranus, and possibly that of Neptune, are retrograde.

13. The reason why the planets and satellites rotate from west to east. This was supposed by Laplace to arise from the fact that, when they were nebulous rings, their sides exterior to the sun moved more rapidly than their interior sides. Afterwards it was objected that their exterior sides, being more distant from the sun, must move more slowly, the same as a distant planet moves more slowly than one more near, and hence that their rotations should be in the opposite direction. But when it was discovered that rotation began, and continued at a more rapid rate on the exterior of the nebulæ, and that the equatorial rings were comparatively thin, it became evident that the exterior of the rings must have had a more rapid motion, and hence that every nebulous body must begin to rotate in the same direction as it revolves.

14. The reason why the three inner rings of Saturn remain unbroken. This has occurred because they are so near the body of Saturn, the nearest being only about 12,000 miles distant, nearer by far than any other interstellar space. They are therefore held in the embrace of powerful centripetal and centrifugal forces, as in a mighty vice. Perturbations have broken the continuity of all other rings, and perturbations from Saturn's outer satellites tend to break these. But as a top, when spinning with great velocity, cannot easily be thrown down, so Saturn's inner rings, being very near his surface, and spinning with extraordinary velocity within a very narrow compass, cannot easily be broken by perturbations from without. I am aware that the continuity of these rings has been attributed to the perturbations of Saturn's moons; but here, as in all other similar cases, such perturbation must have the opposite effect.

15. The ring of the asteroids also receives an easy explanation. When a nebula has reached a velocity sufficient to abandon an equatorial ring, we can see only one cause why rings should cease to be abandoned continuously, one after another, without wide intervals between them. That cause is the varying densities of the outer nebulous strata. Each stratum of the same density must tend to separate by itself alone. But through the entire space of the asteroid belt, when our solar nebula was contracting through a radial distance of a hundred and nineteen millions of miles, — a much farther distance than from our earth to the sun, — the outer strata were nearly of the same density; and hence, through that long distance of contraction, the matter on the equatorial zone was abandoned, not at wide intervals and in large masses, but continuously, and in small quantities. Hence the rings, being very thin, broke up into many small portions, which condensed into small asteroids and smaller meteorites.

The most remarkable fact in the constitution of the asteroid ring is this: through its outer, and therefore its first, space of 65,500,000 miles, there have yet been found only twenty-eight asteroids, nearly equally distributed. But through its inner, and therefore its later, space of 53,500,000 miles, there have been found seventy-seven asteroids. Thus, in the inner and narrower space, there are about three times as many asteroids as in the outer and wider space.

There were also some minor irregularities in abandoning asteroid matter, sometimes more and sometimes less, as was to be antici-

pated from the prevalence of irregularities through all departments of creation, even among the leaves of the trees. But these irregularities are scarcely worthy of notice. Still these minor differences of inter-asteroid spaces have been attempted to be accounted for by perturbations from the larger planets. But the lengths of the major axes of planetary orbits are not altered by their mutual perturbations. And no such cause has ever been shown to be adequate to alter the lengths of the major axes of asteroid orbits. If an asteroid at a nearer distance were transferred to a farther distance from the sun, its mean velocity must be diminished to correspond with its enlarged orbit. But no such diminution of mean velocity has ever been shown to be possible by mere perturbation from a distant planet. It must also be added that these inter-asteroid spaces, a little wider than the others, are being narrowed and filled by the discoveries of additional asteroids revolving therein.

It is an important fact in studying the origin of the asteroids, that they were produced between the formation of two very different classes of planets. The four outer are large, rare, rapid in their rotations, and at wide distances apart. The four inner are small, dense, slow in their rotations, and near together. The very different natures of these two classes of planets are further seen by their diameters when in a nebulous condition. In "The Origin of the Stars," I have given reasons for calculating their densities while in their nebulous condition, as being about fifteen times less dense than the mean density of our nebulous sun when expanded to their several orbits. At that rate their diameters in miles were as follows:—

	Diameter in Miles.		Diameter in Miles.
Mercury	974,400	Jupiter	231,200,000
Venus	4,428,000	Saturn	284,600,000
Earth	6,893,000	Uranus	296,400,000
Mars	4,954,000	Neptune	504,800,000

But the contrast in their diameters is not more wonderful than the contrast in their nebulous densities. Compared with hydrogen, their densities were as follows:—

	How many times more rare than Hydrogen.		How many times more rare than Hydrogen.
Mercury	450	Jupiter	1,092,000
Venus	2,936	Saturn	6,732,000
Earth	7,760	Uranus	54,740,000
Mars	27,410	Neptune	210,600,000

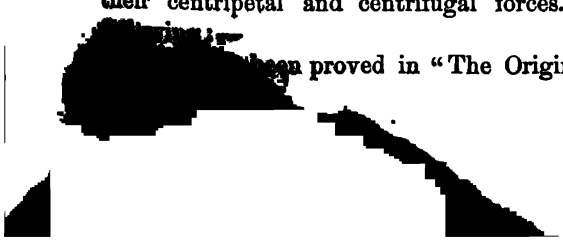
Both in their present condition, and in their early nebulous condition, the difference between these two sets of planets is a great fact in astronomy which has important bearings on other new truths, as I shall attempt to show in my paper on the Meteors. And it was in this transition period of our solar nebula, between the production of these two different classes of bodies, that the rings forming the asteroids were abandoned, — rings vastly different from any others, whether abandoned before or since. The question must hereafter be discussed, What were the conditions of our solar nebula which caused the abandonment of such different planetary and planetoid rings?

16. The ring of the Milky Way also is divested of its mystery by the discovery of the force which produced all nebular action. The same mystery is unveiled by the same means from the similar nebulæ, which are but the milky ways of other sidereal systems. The action of the same formative force shows how the peculiar sidereal systems called planetary nebulæ, elliptical nebulæ, nebulous stars, and double nebulæ, were produced. These explanations have been given in "The Origin of the Stars," and in my two papers published in these "Proceedings" of last year; but additional light may be shed on all sidereal systems, without a central sun, in the following manner: —

(*a.*) It has been clearly shown that the velocity of rotation, in any nebula not retarded by an unrotating interior, will be equal to the velocity of a fall towards the centre of the nebula through its radial distance of contraction. By radial distance of contraction, I mean half the distance of contraction through the diameter of the nebulous sphere.

(*b.*) When our solar nebula was expanded to less than half the distance of the nearest fixed star, say 3,500 times the distance of Neptune, then much less than the $\frac{1}{40,000,000}$ of the entire mass was within the present orbit of Neptune.

(*c.*) If at that period, as I have already pointed out, the entire nebula had rotated ever so slowly, — the interior and the exterior with the same angular velocity, — then the particles of the present orbit of Neptune would have obtained, on arriving by condensation at the orbit of Mercury, a velocity of rotation around the centre of the nebula great enough to balance their centripetal and centrifugal forces. This appears by the



proved in "The Origin of the Stars" that the

mean velocity of any planet in its orbit is to the velocity of a fall from infinite space to the same orbit

As $1 : \sqrt{2}$ or as 1 : 1.41

Therefore	1 : 1.41 ::	110,000, velocity of Mercury	: 154,100
And	1 : 1.41 ::	12,500, „ „ Neptune	: 17,625
		Difference . . .	136,475

Hence the velocity acquired by a fall in our solar system from the orbit of Neptune to that of Mercury is 136,475 miles per hour, a velocity greater than the orbital velocity of Mercury; and, in rotation around the centre of the nebula, more than enough to balance the centripetal force.

(*e.*) But, with so small a portion of the solar nebula within the orbit of Neptune, the particles at that orbit, while condensing toward the orbit of Mercury, would not have attained the great velocity of Mercury. On the contrary, the force of gravity toward the centre would have been extremely feeble, and the motion of rotation of the particles would have been slow, and their centrifugal force would have been weak. Still this feebleness of both the centripetal and centrifugal forces would not have altered their relations; and therefore the equipoise between them would have occurred at the same distance from the centre as if they were more powerful.

(*f.*) Therefore all the solar nebula, except a portion much less than the $\frac{1}{40,000,000,000}$ of the whole, would have been prevented by centrifugal force from condensing at the centre. And our solar system would have had no central body. Our solar nebula would have separated into rings, these rings would have condensed into stars, and these stars would have revolved around their common centre of gravity, which centre would have been empty space. Our solar system would then have resembled the many clusters of stars without a central sun, such as the Pleiades, Coma Berenicis, Præsipe, Kappa Crucis, and others. In this same feature it would have been like the vast majority of sidereal systems. And, in my paper of last year, I pointed out the reasons why sidereal systems generally — such as the annular, the planetary, the elliptical, and the double nebulæ — have no central sun. I also showed why the systems of stars within the ring of the Milky Way, such as our solar system, very generally have central suns.

(*g.*) As the great mass of our solar nebula did not fly off in equipoise between the centrifugal and centripetal forces, but

settled in radial lines toward the centre, we may be absolutely certain that its rotation originally began on the surface only; that at a much later period the interior began to rotate solely by the friction of the rotating exterior; and that this latter period was long after our solar nebula had contracted far within the present known limits of the solar system. By mathematical calculations, founded on the very small proportion of the matter which has been abandoned to form planets and satellites, the size of our solar nebula when its interior began to rotate may be ascertained approximately. But the labor of this calculation has not yet been undertaken.

17. As in the planetary nebulous spheres, and also in our solar nebula, the abandoned rings were not so far apart but that the resulting satellites and planets were powerfully under one another's influence through gravity, so in our sidereal system we are led to believe that the rings and their resulting suns are also bound together by gravity. This is the obvious and natural teaching of the fourth era in modern astronomy. Accordingly I found by calculation that the force exerted by our sun, through gravity, on Alpha Centauri, is such that, to avoid falling into our sun, that star must move at right angles to his present direction at the rate of 145 miles per hour. The light of *Alpha* Centauri is estimated to be 3.30 times greater than our sun's; and if his mass is in proportion, then the sun must move 222 miles an hour at right angles to the direction of Alpha Centauri, to avoid falling into that star. This is on the supposition that our sun is acted on by the mass of Alpha Centauri alone, and without reckoning the combined gravity of both. Sirius gives out at least sixty-three times more light than our sun; and on the supposition that his mass is in proportion, and that our sun is acted on by that mass alone, then our sun must travel at the rate of 580 miles an hour in or near a circle around that great star, to gain a centrifugal equal to the centripetal force.

These new truths are in strong contrast with former teaching. Newton, in his immortal "Principia," utters the following: "The fixed stars being, therefore, at such vast distances from one another, can neither attract each other sensibly, nor be attracted by our sun." One of the latest declarations of opinion is that of Mary Somerville, in her "Connections of the Physical Sciences." She says, "So remote are the nearest of the fixed stars, that it may be doubted whether the sun has any sensible influence on them." It

was not until more than a quarter of a century after the distances of several fixed stars had become known, that this serious error was exposed, and the real truth came to light. This new truth was the direct consequence of the study of the far greater truth, that gravity is the force which gave origin to all stellar motions and all stellar systems. Now, therefore, it becomes the grandest of all problems in astronomy to learn the motions of the stars in our sidereal system. Some one must do for our sidereal system what Copernicus did for our solar system. It is now for the first time absolutely certain that the stars of our sidereal system are bound together by gravity; but, while the amount of this force is known between our sun and a few stars whose distances have been ascertained, the total amount of the force of gravity from all the stars on any single star, our sun for instance, cannot as yet even be guessed at. I look with amazement on the fact that some of the bright suns of our firmament, intrinsically brighter and larger than our own, have velocities from two to three thousand miles per minute; not that these velocities, merely as such, are so wonderful, for we have similar ones in our solar system; but where can we find the gravitating force to impart such velocities to the fixed stars? If the planet Mercury moves at the rate of nearly 2,000 miles per minute, we know precisely where to look for the force which produced that velocity. It is in the mass of our huge sun, which, by contracting and rotating, brought down the material of Mercury in a spirally inclined course while it was floating on the solar equatorial zone. But our sidereal system has no central sun, and we are compelled to look to the combined mass of all the millions of stars in the system for the gravitating power. But when the stars are numbered by millions, and when they are situated at such vast and unknown distances, how shall we estimate their force of gravity? It takes light more than 2,000 years to travel from the outer regions of our system, the Milky Way; and while the visible stars are estimated at 20,000,000, who shall guess at the number of unluminous and invisible stars? In this state of things, while the mind is lost in wonder, and ready to give up the problem in despair, three things are reliably certain. Firstly, the dynamical theorem is proved, that a nebulous mass sufficiently expanded, and rotating through all its strata from its surface to its centre, must separate into rings and resulting stars without a central sun. These stars, like their parent rings, must continue to revolve around their common centre of gravity: they must constitute a system like our vast sidereal

system. The size of the system forms no objection; for dynamical principles operate in the same way, irrespective of size or mass. The inference is inevitable that, as all the rings while separating were acted on by the gravity of the interior nebula with a power sufficient to balance their centrifugal force, so the stars resulting from these rings must be acted on with an equal power in the direction towards the centre, when that interior nebula has all broken up into stars. By learning the distances and the velocities of the exterior stars we may learn their centrifugal force, and hence know their centripetal force, or the gravity and combined mass of all the interior stars. Secondly, the stars of our sidereal system are now acting powerfully on one another, and in some instances with a definitely known force, as I have proved respecting our sun and those stars whose distances are known. Thirdly, the stars of our system are endowed with enormous proper motions, amounting in some instances to two or three thousand miles per hour. Knowing these things, it remains for us to take the course which is so obvious before us. We must institute a system of observations which shall teach us the combined movements of the stars of our sidereal system. Evidently their general movement must be in the plane of the Milky Way; but in which direction? Which way around does the Milky Way revolve? Here we have a problem plainly within our reach. All that is wanting is a series of observations directed to this point by observatory astronomers, and sooner or later the desired knowledge will be in our hands. The fourth era of modern astronomy has in store a new and a larger harvest of magnificent truths than any which has passed. All astronomical laborers will ultimately be compelled to work in this new direction, and in reference to these enlarged views. *Nolens, volens*, they cannot escape. Tycho Brahe did not believe the theory of Copernicus; and yet his numerous observations, more exact by far than any going before, contributed much to establish and develop the Copernican theory. Leibnitz did not believe the Newtonian theory of gravitation, and he declared that it tended to irreligion; and yet the calculus he invented has done more than aught else to advance that theory. Sir John Herschel did not believe the nebular theory of Laplace; and yet his observations and calculations on the double stars, and his discoveries among the sidereal systems called nebulæ, have contributed his full share to illustrate the nebular theory, and the theory of the force by which all nebulous masses received their rotations and their astonishing velocities.

All future discoveries of facts in astronomy, whatever they may be, will not only confirm the nebular theory and the Newtonian theory and the Copernican theory, but in some way or other they will point back to the beginning, and trace their origin to the action of gravity on the universal diffusion of nebula.

18. The infinity of the distribution of matter through space is another sublime consequence of the new discovery of the offices of gravity. Had the nebulous matter been evenly diffused through a finite space, then, on contracting, it would have been all collected by gravity in one mass without rotation in the middle of that space; but the simple fact of rotation proves that the diffusion of matter was not limited to any finite space, for it has broken up into different masses, and these masses, by their interaction through gravity, have produced rotation. Hence the original diffusion of matter must have been through infinite space, so that it could divide into separate masses. Therefore the distribution of sidereal systems must now be co-extensive with the infinity of space. See the beginning of my first paper in these "Proceedings" of last year.

19. The force of repulsion which diffused all matter, and held it permanently through all space against the power of gravity, cannot be lost; but it may be converted, through chemical combination, into light and heat. The absolute immensity of this force the mind fails to conceive, and numbers almost fail to express; and here we discover a source of heat and light almost infinite. In the condensation, therefore, of the great globes of space, we must look for the fires which light up our sun and the other stars; not through a mere fall of matter by gravity, but by the conversion of that almost infinite amount of repulsion. This subject I have developed at length in "The Origin of the Stars," and it is another consequence of the discovery that gravity was the original cause of all stellar motion.

20. The mysteries of meteors and meteorites are solved by the same theory, but a full discussion I must reserve for a separate paper. And here I must close this short review of the new and wide fields of research opened by the fourth era of modern astronomy.

It is an instructive fact that none of these great astronomical eras have appeared such to the generation in which they were made. The theory of Copernicus, announced in 1543, lay almost dormant until the researches of Kepler and Galileo, in the beginning

of the next century. No printer would undertake the publication of Newton's "Principia," not even the learned Royal Philosophical Society of London. It was brought out in 1687 by the private expense of Halley, very much to his own inconvenience. At that period the vortical theory of Descartes was believed and taught in the Universities, and a grand point was thought to be gained many years afterwards when Newton's doctrines were covertly introduced as foot-notes in the text-book of Descartes! Still, a few influential men in London appreciated his work, and he was rewarded with the directorship of the Mint. The nebular theory of Laplace was published in 1796, and we all know how it was neglected by two generations. Now, at length, no epitome of astronomy is thought complete without a brief explanation of that theory. These facts are here mentioned to awaken astronomers to the announcement of the fourth era in modern astronomy. The discovery of the Force which, in the beginning, put all the heavens and the earth in motion, is not inferior to either of the three great announcements of Copernicus, of Newton, and of Laplace.

As the Newtonian theory involves the Copernican theory, and as the nebular theory is founded on the truth both of the theory of Newton and that of Copernicus, so this fourth era includes the ideas of the former three, and goes far beyond them. It announces the first movements of creation! It begins with the action of gravity on the diffusion of nebulous matter slowly contracting. It shows how gravity separated that diffusion into clouds; then how gravity rounded and rotated those clouds, and disposed them in sidereal, solar, and planetary systems. This fourth era reveals the great instrument in the hand of Omnipotence by which the constitution of the material universe was formed! By the constitution of the universe, I mean its systems of revolving and rotating globes, and the distribution of those systems through the infinity of space.

8. The Meteors, and their Long-enduring Trails. By Jacob Ennis, of Philadelphia, Penn.

The subject of this paper is entirely new to science. No investigation has yet been published about the trails left behind by shooting stars, and which float in the heavens an hour or more before our view. When meteors dart through the upper regions of the atmosphere, they are sometimes attended by a train of fire which vanishes instantly with themselves. Sometimes they leave a phosphorescent train which remains a second, or a very few seconds, and then suddenly ceases to glow at the same instant along the entire line. Very rarely they leave a white, cloudy trail which gradually spreads, and then slowly disappears by dispersion in the air. That trail is something material, and may be so dense as to hide the stars. It may extend a mile in breadth, and twenty miles in length, and remain in view an hour, slowly taking different shapes as it bends on the lofty aerial currents. What kind of matter is that which floats up there for so long a time before our eyes, in the thin, cold air? To this question science has hitherto given no answer. But the matter of those meteoric trails is invested with a deep interest. It comes like a messenger from the far distant realms of space, it lodges as a strange foreign body in our atmosphere, and it tells a tale of wonder about the constitution of the universe in regions inconceivably far beyond our planetary orbit.

Before entering on the investigation of these mysterious phenomena, I will here give the accounts of the only two meteor trails ever seen by myself. The first was from Philadelphia, September 5th, 1858, at half-past eight o'clock in the evening. I was sitting at an open window, looking westward: the sky was everywhere clear, and the current of air was very gentle, with a temperature of 78° F. The course of the meteor was from north-west to south-east, and it made its descent at an angle of about 20° with the horizon. The length of the arc described in the heavens was about 40°. As the bright meteor disappeared, the glowing trail which remained in its track instantly riveted my attention. As it was the only one I had ever seen, I watched it carefully, and immediately afterwards I made this record. At first it seemed only six inches wide, and soon it spread to the apparent breadth of one

foot. Its boundaries and both sides were not straight, well-defined lines, but uneven and waving, and becoming more so until it vanished. The duration of the vivid trail after the disappearance of the meteor was only about three seconds. It did not have the appearance of a white cloud shining by reflected light, nor yet was it bright and luminous like the meteor itself. It resembled the pale glowing of the aurora borealis, or the artificial aurora made by the discharge of electricity through a glass tube whose air has been exhausted. It was like the glow of a streak of phosphorus in the dark. I thought at the time it was an electric phenomenon; but now, after a long study of meteoric subjects, I believe, from evidences soon to be detailed, that the meteor was a ball of phosphorus, or something like phosphorus, darting through the air: the trail was the ignited vapor left behind, which in a few seconds was suddenly extinct at the same instant along the whole line. The meteor was the largest I had ever seen, being twice or thrice the ordinary size, though its brightness was not so prominent as to attract the notice of the citizens generally. From its size, motion, brightness, and the length of the arc it passed through, I judged this meteor to have been nearer to me than any I had ever seen. To this nearness I attributed the visibility of the trail.

The next meteor trail seen by myself was from this same city, on August 24th, 1869, at twenty-five minutes after seven o'clock in the evening, and consequently during the very early twilight. Its size was so large as to gain the attention of the citizens to a considerable extent, and the next morning all the city journals gave it a description. My own view was not so satisfactory as I could have wished. I was riding in a car up 19th Street, facing the east: the meteor was seen by the passengers looking west; and the driver rang the conductor's bell to call attention to the wonder. On turning around, I saw the white trail left by the meteor. I was in the condition of a friend of Humboldt, at Popayan, in South America, in the year 1788, who was sitting in his chamber on a bright sunny day at noon, when suddenly he saw his chamber lit up with a more than usual brightness. Turning around toward the window, he saw no meteor, for it had already passed by, but in its path there remained a white streak stretching across the sky (Cosmos, vol. ii. p. 99). In our car the passengers seemed to agree that the long meteor trail was the tail of a comet; but I was certain it could be no comet, but the remains of a shooting star. Its visibility continued about fifteen minutes. From a pre-

vious study of these matters, I was prepared to believe what the appearance then before my eyes rendered probable, that the meteor was a ball composed of some simple chemical element easily oxidizable, such as magnesium, calcium, sodium, or potassium; that it burned spontaneously as it rapidly darted through the oxygen of the air; and that the white, cloudy trail, not at all phosphorescent, but plainly shining by reflected light, consisted of the white, powdery oxide, such as magnesia, lime, soda, or potassa, or some other such analogous substance. It was scattered widely on the disturbed winds by the swift meteor flight, and slowly dispersed and disappeared.

I now proceed to give a collection of nine meteor trails, each one seen by a different set of observers, which have endured about an hour. These are all I have found of so long a period. No author that I am aware mentions more than one. Their long appearances in the heavens have been regarded as a wonder and a mystery, but they have drawn forth no special discussion: they have been an anomaly in science, unexplainable by any existing theories.

1. Humboldt, in the first volume of his "Cosmos," relates that Admiral Krusenstern saw, in his voyage around the world, the train of a fire-ball shine for an hour after the luminous body itself had disappeared, and scarcely move throughout the whole time.

2. During the great meteoric shower of November, 1833, Dr. Ashbel Smith, of Salisbury, North Carolina, was riding all night in a sulky, and he records that by far the most magnificent meteor seen on the morning of the 13th crossed the vertical meridian about three o'clock. Its course was nearly due west. In size it appeared somewhat larger than the full moon when rising. "I was startled by the splendid light in which the surrounding scene was exhibited, rendering even small objects visible. I heard no noise, though every sense seemed to be suddenly aroused in sympathy with the violent impression on the sight. The track of the meteor was visible, forming my estimate from the distance I travelled, for half an hour."

3. Dr. Jared P. Kirtland, of Trumble County, Ohio, wrote concerning the great meteor fall of November, 1833, that a luminous body was distinctly visible in the north-east for more than an hour. He says, "The Honorable Calvin Pease informs me that he discovered it at four o'clock, near the star Alioth in Ursa Major; that it was then very brilliant, in the form of a pruning-hook, and apparently

twenty feet long and eighteen inches broad, and that it gradually settled toward the horizon until it disappeared. I saw it at five o'clock, when it resembled a new moon, two or three hours high, shining through a cloud. About fifteen minutes afterwards no vestige of it could be seen."

4. An unusually large meteor was seen to pass over the New England and the adjacent States, September 20th, 1850. It was seen by W. C. Bond, Director of the Cambridge Astronomical Observatory, while riding in a railway car, and he described the bright trail which it left in its track. In three minutes it had subsided into a serpentine figure, about half a degree broad in its widest part, and ten degrees long. At last it became faintly nebulous, but it could be distinctly seen for more than an hour.

5. J. F. Julius Schmidt, Director of the Astronomical Observatory at Athens, Greece, saw many bolides, large meteors, during the shower of shooting stars, November 14th, 1866. One of these fire-balls was of the first class, which left a trail visible an hour to the naked eye.

6. A very large meteor passed over France and Switzerland, June 13th, 1867, leaving a conspicuous trail. It is described by H. Chist, of Basle, as being "white, semi-transparent, faintly luminous, and visible for the space of about an hour. It disappeared in the approaching darkness after nine o'clock." It was observed by M. L. Roussy, at Toulouse, France, from nine minutes past eight to fifteen minutes past nine o'clock.

7. A few months later, January 1st, 1868, another persistent trail was left by a meteor over the south of England. "On the disappearance of the meteor, there was a narrow line of light, throughout the whole length of its course. The greater part of this disappeared within a few minutes; but, small portions gradually disappearing, it remained, assuming the appearance of very narrow, thin, white clouds. One very short part, say about one-thirtieth of the whole course, was visible for forty minutes, until ten minutes past eight o'clock, when it disappeared immediately over, and in consequence of, the increasing light from the sun."

8. A large meteor, which left a visible trail, was seen on the morning of November 14th, 1868, at a quarter past one o'clock. This trail was watched attentively by practised observers from the following places: Washington, D.C.; Haverford and Wilkesbarre, Pa.; Palisades, N.J.; Poughkeepsie, N.Y.; New Haven, Ct.; and Williamstown, Mass. From the parallax along this base line

of about 400 miles, Professor H. A. Newton, of Yale College, calculated its height to have been about sixty miles. This trail was first straight, soon it received serpentine curves from the currents of the air, and its appearance differed greatly at the time according as it was viewed from the north, or from the south, or from directly below. After remaining visible full three-quarters of an hour, it gradually dispersed in the air.

9. Just one year afterwards, November 14th, 1869, at Pensacola, Florida, Commander William Gibson was observing the usual November meteors of this date. Their frequency was from two to three, occcasionally from twenty to thirty, per minute: their size was from mere moving points to the apparent diameter of Jupiter. The trail of one "remained visible at least fifty minutes, drifting slowly to the northward."

Meteor trails of a few seconds' or a few minutes' duration are well known to the scientific world; but it is very little, if at all, known that such trails endure for an hour as often as I have shown. Humboldt was evidently acquainted with but one, that of Krusenstern. M. Daubree, a Member of the French Institute, and Director General of Mines in France, wrote an exhaustive treatise on the composition of meteorites, which has been translated and published by the Smithsonian Institution in its Annual Report of 1868. He also was acquainted with only the single case of Krusenstern, as is evident when he writes that "Admiral Krusenstern was witness of a fact which should be cited on this occasion." But he merely mentions this as a remarkable and a unique fact, without attempting an explanation. Professor Kirkwood, of the University of Indiana, in his volume entitled "Meteoric Astronomy," also mentions a single case, that of Director Schmidt, the fifth in this collection; and he brings it forward as a large fire-ball on a particular date, without reference to the long persistence of the trail. T. L. Phipson, Doctor in Science in the University of Brussels, in his volume on "Meteors and Aerolites," makes no mention of any of these cases. Professor D. Olmsted, of Yale College, collected in the "American Journal of Science," the numerous observations on the great meteoric shower in America, of November, 1833; and respecting the trails of short duration, and the second and third cases of long duration in this collection, he remarked, "Were the trains and nebulæ merely smoke produced by the combustion of the meteors from which they resulted, and rendered luminous by being elevated above the

earth's shadow into the region of the sun's light? The few remarkable bodies which are described as remaining for a long time stationary in a particular part of the heavens, present anomalies which even conjecture is hardly competent to reach. We shall require more specific facts before we can attempt an explanation." Professor H. A. Newton, of Yale College, has written a paper on meteors; and he collected in the "American Journal of Science," in 1869, the observations on the eighth case in this collection. Respecting the long-enduring trail, he adds, "What kind of matter it is which remains visible in the cold upper air for three-fourths of an hour, until by gradual dispersion the light faded out, I leave for others to say."

The above is all that has ever been said, as far as I can find, respecting these trails of long duration. And there never has been any discussion, nor any full expression of opinion, about "the kind of matter" visible in meteor trails of short duration. Nevertheless some casual assertions, unsupported opinions, have been ventured in scientific writings that the trail consists of the "débris" of the solid meteor volatilized by the intense heat of friction through the air. Haidinger, of Vienna, who has written much on meteors, makes a different conjecture: he says of meteors, that "they may be considered as made up of large balls of dust-like grains; among these is the extrordinary bright one of October 4th, 1854. It was seen in the zenith plainly to turn on its axis, and without doubt it was the dust scattered around which formed the bright shining trail which remained visible. In the case of meteors which remain visible in broad daylight, the trail probably remains visible as cloud or smoke."

Against all this, it is a matter of high import that, of the hundreds of meteors which have reached our earth, not one possesses the property of leaving a white, cloud-like trail if they were dissipated by heat. The dust, the powder, and "the volatilized débris" of all known meteorites, would have been of a neutral shade, — the very dull color which would have remained invisible, except in large amounts, and then the appearance of them all would have been dark, and not white; much less would they have been "bright and shining," as described by Haidinger. Some meteorites are described as having fallen from dark clouds, and such clouds may possibly have been formed of oxidized meteoric dust. But these dark meteoric clouds, from which meteorites have been said to fall, are altogether a different phenomenon from the white trails of meteors

left behind as narrow lines in their paths. On one, perhaps on two occasions, these meteoric clouds have been said to have been white; but it is not certain that they may not have been the ordinary atmospheric clouds of aqueous vapor then casually present.

In presenting what appears to me the true explanation of meteor trails, —

Firstly, I will bring forward many facts to prove that some meteors undergo a process of burning or oxydation while passing through the air, and that the trails are the smoke and ashes of such burning.

Secondly, I will give facts and reasoning which show that some meteors are composed of various simple chemical elements unoxidized, and which are therefore capable of burning in the air.

Thirdly, I will show the order and process of creation by which such meteors were originally formed and left in an unoxidized condition.

I. *Facts which prove that some Meteors undergo a Process of Burning in the Air.*

1. All the appearances of burning, and especially the throwing out of sparks, have been repeatedly seen and reported. The following instance is from the Report of the British Association for 1867, p. 296–7. A meteor, three times as bright as Venus, appeared in England, November 6th, 1866, at fifty-five minutes past five, P.M. Its remarkable peculiarities were its very slow motion and its bright continuance during seven or eight seconds. "From its slow motion, the eye could distinctly see a process of combustion like that of ignited iron wire in a nearly exhausted vessel of oxygen gas." The "American Journal of Science," vol. xxv., contains full accounts of the great meteoric shower of November, 1833. One meteor was described to be as large as a six-inch globe, leaving behind a train of light two or three hundred yards in length, while sparks were flying from the body of the meteor in all directions, until it burst into a thousand particles. From its first appearance until it burst, it continued in view until the number sixty-three was distinctly counted (p. 390). Others are portrayed as follows: "Occasionally one would seem to burst into flames, and burn with increased energy, illuminating the face of terrestrial nature with a degree of brightness and splendor inferior only to sunshine. But

this effect would be of merely momentary duration; for the substance of the meteor would be rapidly consumed, leaving a broad luminous ray, which would perhaps remain distinctly visible for twenty minutes" (p. 377).

2. Irregularities in the amounts of light. Generally the light of meteors continues uniform in brightness, but in some instances the light varies greatly; sometimes dying nearly out, and then again blazing forth with unwonted splendor. A large meteor, whose diameter was one-fifth of that of the full moon, was described in England, November 27th, 1862, as being twice nearly extinguished, and both times it regained its luminosity. Another, about equal to Venus, was seen in England, January 23d, 1868, which disappeared and reappeared further on, almost like another meteor. Such variations we see often in burning bodies in ordinary life, and they may happen from various causes. The burning meteor may become enveloped with a coating of oxide, and then it must cease to burn. This coating may burst off, and again allow all the original burning. Another cause is suggested as follows, in the "British Association Report of 1854," p. 390: "The meteor disappeared for an instant as if completely hidden by a species of smoke which proceeded from it at this moment, after which it reappeared in its primitive brilliancy. One would have said that the meteor in question was undergoing absolute combustion."

This repeated extinction of the meteor's light, and its revival again, is proof perfectly decisive that the light must be caused by burning, and not by mere friction through the air, nor by the latent heat of the air condensed to ignition in the meteor's front. Friction and condensation must yield, if any, a uniform light, and not the dying out and the kindling again, such as burning may produce. I will soon try to show that air compressed in front of a meteor may give out latent heat and a bright uniform light, but that mere friction by a meteor through the air can afford no light.

3. Occasionally, meteors, while flying through the air, suddenly change their course. I can conceive of no cause for these changes but such as may happen very rarely, when the coating of oxide, spoken of above, bursts off from one side only of a meteor, or when the oxide coating is formed on one side only. Then the ignited gas, flying from the burning and relieved side of the meteor, must impel that body in the opposite direction. Such operations we see in the pyrotechnics called chasers, which fly suddenly in zigzag paths.

4. Explosions. Occasionally a meteor is seen to end its course by a brilliant explosion, its fragments sometimes flying out in every direction, and sometimes all keeping on the former course. This harmonizes with the idea that these bodies are metallic, and really burn. A ball of metallic potassium thrown on water will burn, and often it ends its burning by a fiery, meteor-like explosion. The observers, in Professor Olmsted's account of the meteor fall in 1833, speak as follows: "It is well ascertained that several of the meteors appeared to burst into numbers of smaller stars as they fell" (p. 272). "And, when approaching the earth, they burst (I could not detect either explosion, snapping, or cracking) into innumerable spangles or smaller stars, precisely as a rocket does" (p. 390). "At other times some meteors would appear, and pass through an arc of 5° or 6°, when they would explode, and the new-formed meteors possess all the features of the original one, passing very nearly in the same direction" (p. 380). Explosions over Great Britain, November 12th, 1837, are described as follows: "At eight o'clock in the evening, the attention of observers in various parts of the country was directed to a bright luminous body, apparently proceeding from the north, which, after making a rapid descent in the manner of a rocket, suddenly burst, and, scattering its particles in various beautiful forms, vanished in the atmosphere. This was succeeded by others, all similar to the first, both in shape and the manner of its ultimate disappearance." The explosion of the meteors seems to proceed, like that of potassium on water, from the sudden presence of so much oxygen that it thoroughly ignites all through, and thus flies asunder, every fragment being intensely luminous. This is a very different phenomenon from the explosion of oxidized meteoric stones. The latter become suddenly heated externally by the revival of the latent heat of the air, and they break, as we often see a heated glass, or a heated stone or porcelain, break. Such explosions are often without any light.

5. Phosphorescence. There have been plain unmistakable appearances that some meteors consist of phosphorus, or some other unknown simple element similar to phosphorus. This element is very easily vaporized, and as it darts in a blaze through the air it may leave behind in its path a copious stream of vapor. This vapor oxidizes and burns, sometimes with a pale glow and sometimes intensely. In all cases it suddenly goes out along its whole line at once. This sudden extinction alike through its entire course, as well as its peculiar look, is decisive. When the vapor

is all burned it must at once cease to shine. The ashes and smoke of meteors composed of other simple elements behave very differently. They gradually fade away by the dispersion of the ashes through the air. In the great meteoric fall of November, 1833, the following are the independent reports of three different and far-distant observers: "The light of their trains also was of a pale hue, not unlike that produced by writing with a stick of phosphorus on the walls of a dark room" (p. 365). "The long, luminous traces which they left behind would last for several seconds; and at times, when the nucleus had entirely disappeared, these traces or streams, varying from ten to a hundred yards in length, would linger in the sky and continue to shine with all their brilliancy for two or three minutes, and then suddenly expire in a twinkling of an eye" (p. 382). "By far the most brilliant one which we saw occurred at a few minutes past five in the morning, and seemed to announce by its splendor the finale of this grand exhibition of fire-works in the heavens. It seemed to pursue, as near as we could judge, a course from S.E. to N.W., the ball being apparently five or six inches in diameter, with a train from thirty to forty feet in length; the *latter* assuming immediately, on the passage of the meteor, a serpentine form, and diffusing a light upon the earth fully equal to that of the full moon, and remaining *intense* at least for forty or fifty seconds" (p. 380).

Thus we have evidence of three very different kinds of meteor trails never before discriminated. First, meteors of phosphorus, whose trails have a fiery glow, and which disappear instantly throughout. Second, meteors composed of some easily combustible simple elements, such as potassium, sodium, calcium, magnesium, and the like. They burn, and their ashy trails seem white and cloudlike; and, after remaining visible from a few moments to an hour or more, they disappear by a slow dispersion in the atmosphere. Thirdly, meteors composed of oxidized materials, stony meteors, and also metallic iron meteors. Their light and heat spring from the compression and the latent heat of the air, not from mere friction as is generally supposed. They may be so intensely heated on their surfaces as to be ignited and vitrified, and their glowing exteriors may leave behind a short fiery trail instantaneous only in duration. They have been aptly compared by observers to a fire-brand carried against the wind.

6. Various colors. It is well known that meteors have different colors, such as white, red, green, and blue. These colors harmonize

with the fact that their light springs from the burning of their simple chemical elements. These elements, we know, burn with different colors. And thus shooting stars have different colors from precisely the same reason that the other larger stars shine with various lights.

7. It has been announced on sufficient authority that the meteors of the November stream become incandescent at a greater height than those of the August stream. This fact cannot be accounted for by either of the two old theories of meteoric light, that of friction, and that of latent heat in the air. But this remarkable phenomenon at once proves the truth of the combustion theory, and that the meteors of the November stream are composed of very different simple elements from those of the August stream, and that therefore they burn at a higher altitude.

8. The sizes and the densities of meteoric trails prove that they are the products of combustion. Their densities are such that they have repeatedly been seen to occult the stars, and they are sometimes a mile in diameter and fifteen or twenty miles in length. Where they end they stop abruptly, showing the point where the meteor is entirely consumed. All this is entirely different from the volatilized débris of stony or nickeliferous iron meteors. This latter débris is either incandescent "like the flame of a firebrand carried against the wind," or else it is invisible. Stony and iron meteors show no evidence of being vaporized altogether in the air. They reach the earth in their course, and they may be handled and analyzed; or perhaps they may go on and fly away from our globe in a conic section. Several of them have been known to traverse the earth's atmosphere a thousand miles and more without any signs of being dissipated by frictional or by revived latent heat. Their phenomena stand out in marked contrast from those of combustible meteors, whose trails are short, broad, and dense, with abrupt terminations, and with a chalky whiteness equal to the whitest cloud. The intense burning of the meteor violently throws off the smoke and ashes half-a-mile on every side. My own lecture room includes a space of 20,000 cubic feet, and I have often wondered to see how suddenly it can be entirely filled by the dense white fumes of a ball of burning phosphorus. The long persistency of the white ashy trails in the upper air I have seen paralleled by the persistent trail from a volcanic cone rising upward a couple of miles or more, and sailing off laterally several miles unbroken on the trade winds. Such a stream from a tall volcanic

peak on the island of Lombok, east of Java, curved about gracefully on the breeze in various directions. The monsoons were just changing, and the aerial currents were various, and the dark gray line of smoke and ashes rose in one curve far above the region of the clouds, and fell in another curve down on the ocean waves. Once it struck our ship, and filled it with a strange sulphurous odor, as if coming from the bottomless pit.

9. I know not under which of the foregoing heads to arrange the following case; but, as it affords so strong an evidence of combustion, it may stand by itself and close this catalogue. The meteor was seen by many observers, both in Alabama and Mississippi, July 8th, 1856, at about five o'clock in the afternoon. It was reported in the "American Journal of Science" soon after, by Professor N. K. Davis, of Howard College, Marion, Alabama. Its very conspicuous trail was one degree broad and eight degrees long, and it remained visible fifteen minutes. One observer, Mr. Thomas M. Peters, compared it to "a dense body of steam projected in the air, and to the dense white smoke of a cannon." Professor Davis says, "The fumes were densely white, and reminded me strongly of the fumes of a chloride formed when powdered antimony is projected in a jar of chlorine. The cloud gradually took a zig-zag form; and the aerial currents then slowly dispersed it, though it retained its dense appearance after it had spread considerably. I have never seen a notice of a similar fact, and the question arose in my mind, May not the luminous trail left by nocturnal meteors be due to the momentary phosphorescence of similar fumes? I say fumes, because I suppose the cloud to be the product of combustion in the air; but what this product may be, from its appearance alone, I would be at a loss to determine."

When a thing is plainly seen to burn, that ought to be an end to all controversy; but while numerous observers have so often declared that meteoric light and heat are sometimes phenomena of burning, why have not scientific theorizers accepted the fact? Why have they ignored combustion, and resorted to friction and to latent heat? This is because they have seen nothing in meteorites to burn. Meteoric stones certainly cannot burn, for they are oxidized already. And metallic meteors, composed mainly of iron and nickel, cannot burn, because they are too solid and massive. But in the next part of this paper I will try to show that the reason why the easily burning meteors have never reached the

surface of the earth is because they have all been necessarily burned up and dissipated in the atmosphere.

II. *Facts and Reasonings to prove that some Meteors are composed of Simple Chemical Elements which burn spontaneously in the Air.*

Meteors composed of potassium, sodium, lithium, strontium, phosphorus, and others of a similar nature, could not possibly come down to the surface of the earth. They would take fire at very great heights, and strew their white oxidized materials as trails on the winds. They would naturally be scattered over spaces thousands of miles in extent, as is often the case with volcanic dust, and their fall would be imperceptible. What now are the grounds of belief that some meteors are composed of such simple elements spontaneously combustible in the earth's atmosphere?

It is a great fact, hitherto but slightingly regarded, that in meteorites the following chemical elements are found unoxidized: phosphorus, sulphur, carbon, silicon, chlorine, magnesium, calcium, aluminum, arsenium, manganese, tin, chromium, cobalt, nickel, iron, and copper. It is well known that meteorites are divided into meteoric stones having their elements completely or partially oxidized, and metallic meteors composed mainly of unoxidized iron and nickel. Along with the iron and the nickel have been found, in less abundance, the remaining fourteen elements of the above catalogue, all unoxidized. In some meteorites, indeed, with very little or no iron, there have been found notable amounts of free sulphur and carbon; the latter in the form either of plumbago or of charcoal, as in the meteorite of Alais.

This great fact of the unoxidized condition of so many simple elements may be regarded as an astronomical fact. It is wholly different from terrestrial phenomena. Here, on earth, the elements are invariably found in an oxidized state, except where we see agencies at work deoxidizing them; as the plants which liberate carbon, and the volcanoes which liberate sulphur. It may be that some comparatively small amounts of copper, including the mines of Lake Superior, have never been oxidized. Being very heavy, some portions of that metal may have sunk below the region of the light oxygen gas when our planet was all ablaze. Gold is unoxidized, because by no natural process does it combine with oxygen; and, even if it were so combined, the heat of our flaming planet would have set

it free. Here then we listen to a great wonder told by meteorites which come to our planet from the far-distant planetary spaces. It is that the simple elements in some remote astronomical regions are unoxidized. Why they are in that condition I will soon disclose. We have now to do with the naked fact. The simple elements in meteors are twenty in number besides oxygen. If sixteen of these exist unoxidized, contrary to all terrestrial experience, why may not the other four, potassium, sodium, lithium, and strontium? There is indeed no reason why we may not see a meteor of potassium and sodium unoxidized as well as a meteor of iron and nickel unoxidized. Existing alone in such a condition, the potassium meteors cannot possibly come down to the surface of the earth. They must necessarily burn brightly and beautifully on entering our atmosphere; and, if they be large enough and near enough, they must leave a white visible trail stretching along their paths, and waving slowly on the breeze. A meteor composed of phosphorus would leave, as already stated, a phosphorescent train, perhaps very pale, and perhaps very bright, depending on the amount of vapor. Possibly after the light of the vapor is suddenly gone out, the white fleecy fumes of phosphoric acid may in some cases be visible. These burnings and these trails, be it remembered, are the best possible evidences we can have that those four alkaline elements in meteors — potassium, sodium, lithium, and strontium — may sometimes come pure and simple.

There are, however, other evidences, which to other minds may appear stronger, such as that from the spectroscope. The Report of the British Association for 1866 contains the following: "That which the spectral examination of the August meteors has most clearly brought to light is the existence of an extraordinary quantity of the vapor of sodium in the luminous streaks, so that many of these streaks, especially the most conspicuous and the most slowly fading among them, *consist of nothing else but soda flames* for a great portion of the time they continue visible."

Therefore we have three very strong evidences that potassium, sodium, lithium, strontium, and other like elements, may form meteors in an unoxidized state.

Firstly, because at least sixteen of the meteoric elements [illegible] in a pure unoxidized condition.

Secondly, because we behold meteors burning in the air, and the phenomena of burning, as detailed at length in Part I. of this paper.

Thirdly, because of the teachings of the spectroscope.

But how has our solar system been so constituted that here on our planet there are sixty-three elements always oxidized, while in the outer regions we know of only about twenty-one elements, and these are often unoxidized? This leads us to the third part of this paper.

III. *The Process and Order of Creation by which Meteors were formed with but very few Elements, and these few were often left in an Unoxidized Condition.*

To make this process clear, I will show —

First, that the meteors which reach the surface of the earth, stony meteorites and metallic meteorites, come from the region of the solar system, within the ring of the asteroids.

Secondly, that the unoxidized meteors, which burn and leave their phosphorescent and thin ashy trails in the air, come mostly, probably altogether, from the more distant regions of the solar system, beyond the ring of the asteroids.

Thirdly, that the meteors with visible trails were left unoxidized because, at the period of their creation, the simple element oxygen had not yet been formed, and therefore that the era of the creation of oxygen, as well as of many other elements, was not before the creation of the ring of the asteroids.

First, the following are the evidences that the meteorites which reach the surface of the earth come from within the ring of the asteroids.

(*a.*) Their density. The matter of the solar system beyond the ring of the asteroids formed very rare and light bodies, as we see in Neptune, Uranus, Saturn, and Jupiter, and their satellites. Compared with water, the densities of the planets are as follows: —

Mercury	6.71	Jupiter	1.32
Venus	5.11	Saturn	.76
Earth	5.44	Uranus	.97
Mars	5.21	Neptune	.76

Here it is plain that the four outer planets differ from the four inner in so great a degree as to prove that these two sets of celestial bodies are composed of very different materials. For other comparisons, never before given, on different points between these two sets of planets, see my paper on "The Four Great Eras

in Modern Astronomy," in these "Proceedings," and also "The Origin of the Stars," sections 25 and 30. The densities of the meteorites vary from 1.97 to 7. Generally they are about like the density of the earth, which shows that they belong to the inner class of planets. It is most unscientific to suppose that matter in the outer region of the solar system should condense into light bodies when forming planets and satellites, and into heavy bodies when forming meteorites. On the contrary, when we consider the great pressure of the materials upon themselves in the large outer planets, their immense force of condensation, we must believe that those large planets are denser than the small meteors of that region, the same as the earth is denser than the moon, and Jupiter is denser than his satellites. The rare meteors from that outer region I shall show are those which burn in our atmosphere and never reach the ground except as gas or invisible powder.

(*b.*) The nature of the elements forming meteors, and also those forming our earth, could not, by any possible combination, form such rare bodies as the four outer planets. Therefore, in the process of creation by nebular condensation, the meteorites could not have been formed in those outer regions. The outer planets are solid bodies; and, by the views of the solid prominences on Jupiter and Saturn, the times of their rotations have been determined. But meteoric and terrestrial elements cannot, by the laws of chemical combination, form such light solids. All earthy inorganic solids are much heavier than water. Even our light gases, oxygen, hydrogen, nitrogen, and chlorine, combine among themselves to form solids more dense than the outer planets. Chlorine, hydrogen, and nitrogen unite to form the solid sal-ammoniac, or hydrochlorate of ammonia. Oxygen, nitrogen, and hydrogen unite to form the solid nitrate of ammonia. Both these solids are denser than the four outer planets. Oxygen and hydrogen unite to form water, which, as solid ice, is denser than Saturn, Uranus, and Neptune. It is a little lighter than Jupiter, but this cannot be Jupiter's composition. I need not occupy space to show that a great and beautiful globe, 88,000 miles in diameter, doubtless the abode of high intelligence, cannot be composed mainly of ice. Thus we see that neither the elements of meteorites, nor even those of our earth, can form bodies like the four outer planets. Hence we may conclude that such elements do not form small meteorites in those outer regions.

(*c.*) Still other reasons prove that the four outer planets are

composed of very different elements from those in the meteorites or in the earth. If their elements were not different, no living being could be there. Neptune is thirty times more distant from the sun than our earth, therefore as 30 × 30 = 900, the region of Neptune is 900 times colder than that of our earth. Water and all other known liquids would be solid there. Hence all must be dreary death in those large magnificent globes,— a most absurd idea, — unless the elements are different. It is true that unusually large atmospheres in those planets might prevent the escape of much solar heat, but not enough to make up so enormous a deficiency. On the other side, Mercury is glowing in the close neighborhood of the sun, and water would boil and evaporate there. Mercury receives 6,200 times more solar heat than Neptune. Hence the different planets, doubtless all noble abodes of life, all differ more or less in the elements of their constitutions. Meteorites formed according to the nebular theory, in the different planetary regions, must differ accordingly.

(*d.*) We further learn that meteorites do not come from the outer regions of our solar system, because the streams of meteors from those regions, the August and the November streams, contain no meteorites. All those millions of meteors are composed of unoxidized elements which, on touching our atmosphere, burn and display their phosphorescent or their snow-white trails. Professor Kirkwood, in his "Meteoric Astronomy," gives a catalogue of meteorites and bolides, or large fire-balls, which have fallen between the years 1548 to 1866, in the November meteoric period. The fire-balls have nothing to do in the case, as they may not have been meteorites; but he finds only four falls of meteorites on the meteor days in all that period! He also gives a like catalogue of meteorites in the August stream of meteors from date 1642 to 1863, and finds only ten! And these ten were not on any one day of the month, but distributed during five days, from the 7th to the 11th. Professor Reichenbach, very learned in this department of science, estimates the number of meteorite falls every year to be 4,500, or an average of about twelve daily; therefore the ten falls during the five days at the time of the August stream of meteors in all the 220 years, and the four falls at the time of the November meteors in all the 320 years, have not a particle of weight to show that meteorites are a part of those meteoric streams from the far-distant regions of the solar system. They prove, in fact, just the reverse: especially when we consider the many millions of those

meteors which burn during the August and November periods. Professor Olmsted calculated that the number visible at New Haven alone was a quarter of a million in the single shower of November, 1833. Each one of the three great showers of 1799, 1833, and 1836, must have contained many millions of meteors, and yet they are not known to have yielded a single meteorite. As the meteors of the November stream come from beyond the orbit of Uranus, and as those of the August stream come from beyond the orbit of Neptune, how can we have better proofs that meteorites do not come, along with the other shooting stars, from the region of the four outer planets?

Secondly, the unoxidized meteors, which burn and leave their phosphorescent and their ashy trails in the air, come mostly, probably altogether, from the more distant regions of the solar system, beyond the ring of the asteroids.

This is evident about the millions of meteors in the August and November streams, and there are no known facts to the contrary about any other meteors, except those composed of meteorites. But in passing through, or even near by, the great meteoric streams from the outer regions of the solar system, — and those streams are probably numerous, — the gravitation of the earth must necessarily cause many millions of meteors to abandon their native streams, and to revolve in elliptic orbits around the earth. Dr. Weiss in the "Proceedings of the Vienna Academy," vol. 57, has shown that these orbits must vary in their periods from one and three-quarters to 390 years. By still further perturbation, these meteors may daily and even hourly enter our atmosphere and burn. It is wonderful to think that while our earth is revolving around the sun, it is attended with so immense a swarm of these millions of inflammable satellites, and that their numbers are annually increasing and hourly diminishing.

The nine meteor trails of long duration, collected in the beginning of this paper, belong mostly, perhaps altogether, to the epoch of November 13th, 14th, as shown by the following dates. The only three not in the precise date of the epoch may have been drawn from the stream in elliptic orbits, and afterwards by further perturbation to the earth's surface.

1. Date unknown, Wrangel's meteor.
2. November 13, 1833.
3. November 13, 1833.
4. September 20, 1850.
5. November 14, 1866.
6. June 13, 1867.
7. January 1, 1868.
8. November 14, 1868.
9. November 14, 1869.

In this same epoch a large number of trails have been reported, lasting from fifteen to twenty minutes. Thus it appears that very much of the matter seen floating so often from fifteen minutes to an hour in the upper strata of our atmosphere belongs to the November stream of celestial bodies, and that it comes from the region beyond the orbit of Uranus.

Enough has now been said to show that there are two classes of meteors, corresponding to the two classes of planets, — the outer and the inner, the distant and the near: the one yielding heavy, stony, and metallic bodies, often wholly oxidized; the other is unoxidized, and they burn spontaneously in the air, leaving phosphorescent and ashy trails. The ring of the asteroids seems to be the dividing line between them; and this fact is significant respecting both the original formation of the ring, and also the cause of the very wide difference between the outer and the inner classes of planets and meteors.

The question cannot be repressed whether the matter of these ashy trails may not be detected in the surface of the earth? But it has been falling so long that it must now be a constituent element of our globe. It fell during the millions of years while our globe was incandescent, and the ocean was all vapor. It fell during the millions of years when the ocean covered the globe, and when there was no dry land. It fell during the millions of years when the stratified rocks were deposited little by little as sediment in the bottom of the waters, and therefore it must penetrate all those strata. It has therefore become so incorporated with our globe as to be undistinguishable, certainly at present. Perhaps hereafter spectral analysis may detect minute portions of some element pervading the earth's crust everywhere, and which may be ascribable to a foreign origin. It is a great fact that three of the metals on the surface of our globe — sodium, potassium, and lithium, all spontaneously combustible in the air — are lighter than water, like the outer planets whence come the August and November streams of meteors. These three elements, as well as phosphorus, appear by their lightness to belong to that outer region, the same as the heavy meteorites certainly belong to the inner class of planets. Combined with oxygen, they form bodies heavier than the outer planets; but most probably they combine with some other gas or gases which we see in the atmospheres of the outer planets, and thus help to form the solid bodies of those great globes.

We now go on to account for the unoxidized condition of many meteors.

Thirdly, the meteors with visible trails were left unoxidized, because at the period of their creation the simple element oxygen had not yet been formed, and therefore the era of the creation of oxygen, as well as of many other elements, was not before the creation of the ring of the asteroids. In speaking of the creation of a simple element, we do not mean the creation of matter. The simple chemical elements I have elsewhere shown to be mere modifications of an original form of matter; hence all the elements I have shown to have at least fourteen fundamental properties in common, and they differ in about six secondary properties, which latter have been caused during the long process of nebular condensation, partly in the original solar nebula, and partly in the special planetary nebula whose solidification formed the earth.

We have already seen that the meteorites were not created before the ring of the asteroids, and now we show that, at the period of their creation, oxygen had not yet been formed in sufficient amount to oxidize them. Not one-tenth of the mass of meteoric matter already found, probably, indeed, not the one-hundredth part, is oxidized. Sixteen of their twenty elements have been found unoxidized. Meteorites exhibit unmistakable evidences of having been deposited, like frost, snow-flakes, and hail, from a state of vapor. In this state of vapor their simple elements were mixed together most intimately, as now appears from their composition; and, if the amount of oxygen then created had been sufficient, all their elements would have been thoroughly oxidized. To exhibit the intimate mixture of the elements before solidification, and while yet in the vaporous condition, I have taken the pains to construct the following table. These meteorites are scattered through the work of Dr. Phipson on Meteors, who gives the authorities. The first column contains the name of the locality where the meteorite fell; the second and third, the time; the fourth, the number of elements in the meteorite; the remainder, the percentage of those four elements,—the silica fifth, magnesia sixth, the lime seventh, and the alumina eighth.

1	2	3	4	5	6	7	8
Juvenas	1821	June 18	12	49	6	10	12
North America	1827	May 22	15	39	22	.7	4
Cape Gd. Hope	1838	October 13	19	30	22	1	2
Brabant	1840	June 12	14	20	15	2	4
Utrecht	1843	June 2	16	39	24	1	2
Nordhausen	1843	September 16	15	33	26	2	3
Hungary	1857	April	16	34	22	.6	5
Transylvania	1857	October 10	13	36	23	trace	.2
Hungary	1858	May 19	14	41	27	.8	2
Louvain	1863	December 7	12	37	24	2	3
Orgueil	1864	May 14	17	26	17	1	1

It is wonderful how many of the twenty-one meteoric elements are often contained in the same small stone; in one case as many as nineteen. Besides the above, it is instructive to note the Braunau meteorite, which fell July 14th, 1847. The number of its elements is fourteen, *all unoxidized;* they are as follows: phosphorus, sulphur, carbon, silicon, chlorine, magnesium, calcium, arsenic, manganese, cobalt, chromium, copper, nickel, iron. A very small meteorite, described by Professor Shepard, weighed only half-an-ounce. It was round, and slightly pear-shaped, and contained seven or eight elements, all unoxidized, as follows: "sulphur, carbon, cobalt, tin, nickel, copper, iron, and possibly chromium." How wonderful! Here is a meteor with the weight only of an ordinary letter we send to the post-office, and yet it contains seven or eight elements! How thoroughly do all these facts show the mixture to have been! The same truth is further proved by the way the elements are associated. In some meteorites the unoxidized portions are seen as small specks, often merely microscopic; in others these specks are seen larger; in others, still larger; and so on until the unoxidized portion is the larger part of the mass, and at length it forms the entire mass. All this is in conformity with a well-known chemical law, that the more easily oxidizable elements combine first with the oxygen, and when they are satisfied then the oxygen combines with those less easily oxidizable. In this way the copper on the bottom of a ship is preserved from rust or oxidation by fastening on the copper small pieces of a more easily oxidizable metal: these keep up the oxidizing process, and the copper is saved. In the meteorites, therefore, it was conformable to law that some elements should be oxidized before others; but if the oxygen had then existed in sufficient amount, all the elements would have been oxidized.

The above table exhibits the further important fact that, at the period of the formation of the meteorites, other elements besides oxygen had not yet been created in the same proportions as they have since been created in our earth. The magnesia, for instance, existed then in amounts nearly as large as silica, and far in excess of lime. In our earth it is now far less plentiful than lime. The iron also was in great excess as the oxygen was deficient.

These facts about the proportionate amounts of the elements then created are of the same order as the still greater fact, that about forty of our terrestrial elements had not then been created. Had all the elements of our earth been then created, doubtless in that thorough commingling of elements we should have found them all, or nearly all, in the meteorites; because thousands of meteorites have been sent down as specimens to inform us of the elements then existing, and showing us thereby the great and sublime history of creation.

All these numerous facts lead us to believe that the simple chemical elements — mere modifications of some original form of matter — have been formed successively in the process of nebular condensation. At first, in the outer regions of the solar system, they were very few and very light. Then more and more were brought into being, of a denser constitution, both in the general solar and in the several planetary nebulæ. The means by which they were created — the physical forces — and the proofs of the process, I have dwelt on at length in "The Origin of the Stars," sections 13th and 6th. At present I can simply point out how this view explains the large collection of facts in this paper.

1. When the solar nebula was so expanded as to inclu
orbits of the outer planets, it must have been inconceivabl
and at that period, accordingly, the rarer elements and t
planets were created. Neptune, Uranus, and Saturn can
sibly be composed of such elements in general as those
globe. Still, such rare metals as are lighter than water —
lithium, and potassium — may be there combined with som
gases peculiar to those planets, but not with oxygen and hyd
Metallic potassium, when combining with oxygen and hydro
form the dry solid hydrate of potassa, undergoes a condens
such that a cubic space which holds 430 atoms of metallic p
sium will then hold 700 atoms of potassium, 700 atoms of hy
gen, and 1,400 atoms of oxygen: 2,800 atoms in all. An enorm
condensation, say from 430 ounces to 2,800 ounces in the sa

space, and far surpassing those planets. I have already pointed out how those four outer planets cannot be formed even of the rare gases of our globe.

2. Because oxygen had not been created in the outer regions of the solar system, the meteors coming from there — those, for instance, of the November stream — are all unoxidized, and they burn brightly on touching our atmosphere. The spectroscope shows that those meteors sometimes consist of pure sodium. Scientific men have said nothing of this fact, because no theory in the books can account for pure metallic sodium in the meteors.

3. The occasional unoxidized condition of at least sixteen elements in meteorites is likewise accounted for by this theory. Oxygen had not yet been formed in sufficient amount to combine with them all.

4. It accounts for the proportions of the elements in meteorites so different from their proportions in the earth; such as the excess of the iron and magnesia, and the deficiency of the lime and the oxygen.

5. It accounts for the small number of elements in the meteorites, only about twenty-one.

6. It accounts for the two different classes of meteors, corresponding to the two different classes of planets; the one yielding light, ashy, or phosphorescent trails in the air, and the other yielding heavy meteorites which reach the ground.

7. It accounts for the forty additional elements in our globe, created since the meteorites in the nebular condensation of our planet.

8. It accounts for the vast number of additional elements in the sun. The fixed lines in the solar spectrum show that hundreds of elements have been formed in the nebular condensation of the sun since the parting of our earth as a nebulous ring.

9. It accounts for the vast variety of the simple elements in the fixed stars, as seen in their dark spectral lines. Although all have been formed from the same general diffusion of matter, still, in condensing, each one has varied from the others in forming its elements, following the rule that no two objects in creation are alike.

10. This theory accounts for the abnormally rare condition of the sun. There is a law of density in the solar system which the sun does not yet obey, but which it will obey hereafter. The law is that the exterior is rare, and the interior is dense. The interiors

of the earth and of the other planets are denser than their exteriors. The planets are denser than the satellites, because the satellites are exterior. The interior planets toward the sun are far denser than the exterior planets. The sun, according to law, ought to be the densest of all; and such it will hereafter doubtless be. Now it is the only live body in the system: all the others are dead and cold. It is still undergoing the process of condensation, which process, by the combination of its elements, produces heat and light. New elements there are still forming and combining as they once did in our planetary nebula, when forty new elements were wrought out which are not in the meteorites. The volcanic heat in the interior of our globe, and the ashy constitution of its crust, are witnesses of the fact. When the sun shall attain the normal density of the solar system, his diameter will be reduced about one-half. How long before that will be we cannot tell.

We cannot tell how many new elements are yet to be formed, nor how long they will burn. To the burning of even those now in the sun we can set no limits. The dark fixed lines in the solar spectrum proclaim hundreds of elements to be there of whose properties we know only the fact that they can send out a most wonderful supply of heat and light. How long they will continue to do this we cannot begin to guess. There are astonishing extremes in all the properties of matter. Platinum is a quarter of a million times more dense than hydrogen. Let us suppose that some of the solar elements can give out a quarter of a million times more heat than charcoal. A charcoal sun, according to accurate calculation, would burn about 5,000 years. Multiply 5,000 by a quarter of a million, and we have 1,250,000,000 years for the sun to give out his present rate of heat and light by burning. We do not say that the solar elements can give out exactly a quarter of a million times more heat than charcoal. We only say that no man knows how much heat they can give out; and therefore we have not a particle of foundation for setting any limits more or less to the duration of the heat from burning in the sun. To scout the idea of a real burning in the sun, as some do, on the ground of the insufficiency of solar fuel, appears to me the most unscientific and the most absurd of all ideas. There is a rashness and a presumption in the act which is to me astonishing. How do you know, wise objector, how long the elements of the sun can burn? Plainly you know nothing about it. You go on the presumption of the uniformity of matter. A charcoal sun can burn

only 5,000 years, and therefore you infer that nothing else can burn longer. But the wonderful diversities of matter in every respect — not its mere uniformities — must be considered. Water requires twenty times more heat than mercury to raise its temperature a single degree. Mercury melts at 40 degrees below zero, and platinum at 30,000 degrees above. Oxygen is about 39 times more diathermous than chlorine, and 1,195 times more than the gas ammonia. Rock-salt is 92 times more diathermous than Iceland spar. The difference of the heat-giving powers of the various elements when they combine is beyond computation, some being almost or quite insensible, and others being many thousand times greater. We cannot say that because one simple element is a quarter of a million times more dense than another, therefore some elements in the sun can give out a quarter of a million times more heat than any in our earth; but this we say, with the utmost confidence, that, considering the wonderful diversities of matter, we cannot set limits to the heat-giving power of the solar elements. It is absolutely nothing to say that about a dozen of our terrestrial elements are seen in the solar spectrum. We must rather look to the hundreds of elements peculiar to the sun when we estimate the solar power. It is just as unscientific to say that the extreme intensity of solar heat must separate rather than combine the elements. This divellant power of heat between two elements is also a matter of degree. Gold and oxygen are separated by a small amount of heat. No furnace can separate iron and oxygen, or carbon and oxygen. The alkaline metals and oxygen were separated by Davy's battery; but how much of that was done by heat, and how much by electric and magnetic force, we know not. Even if it were done by heat alone, we cannot say that the peculiar solar elements can be separated by such degrees of heat. It must be remembered that all the probabilities are in favor of the chemical theory of solar heat, which probabilities and positive evidences I have detailed in about two hundred pages in my volume. And if we reject the chemical theory we have no theory at all. The meteoric theory, once so prominent among scientific men, I showed to be utterly insufficient in my paper on the "Mechanical Theory of Solar Heat," in the "Proceedings of the Academy of Natural Sciences of Philadelphia," for the year 1867. Since then, although prominent before, the meteoric theory has been no longer believed. Six months before my paper, Kirkwood, in his "Meteoric Astronomy," gave his decided adhesion to the meteoric theory, as well as

other scientific gentlemen about that time; six months after the date of that paper, Croll, in the "Philosophical Magazine," writing on the duration of solar heat, entirely ignores the meteoric theory. Perhaps I am mistaken, and some one besides myself refuted that theory just at that date: if so, I will be thankful for the information.

While the theory of combustion, or the burning of the meteors in the air, accounts for the light and heat of the great majority of the shooting stars, it does not account for all. Some meteors are composed of oxidized stones, and others of solid masses of iron, and these plainly cannot burn. Previous to the burning theory developed in this paper, there have been three other theories for the ignition of meteors. The one of these, which is now very generally adopted, ascribes the heat to the friction of the meteor against the air. The theory of latent heat seems to be scarcely known. It is founded on the fact that the air contains what is called latent heat. The higher and the more rare, the greater is the capacity of the air for latent heat. Therefore, in the extreme upper regions of the atmosphere, the greatest abundance of the latent heat is lodged. It is revived and rendered sensible by the compression and condensation of the air in front of the meteor as it flies along. Hence meteors ignite at very great heights; and when they come down to the denser strata of the atmosphere, where the latent heat is less abundant, the light of the meteor invariably goes out. This is proof of the most decisive nature in favor of the latent heat theory, and against the friction theory. In the lower and denser atmospheric strata, the friction must be the strongest; and, according to the friction theory, the heat and light should be the most brilliant. But, instead of this, these strata are the region where the meteors suddenly and invariably cease to shine. Not one has ever been seen to come incandescent to the ground.

It cannot be maintained by the advocates of the friction theory that the meteors cease to shine because their velocity is lessened by the friction, or because they are vaporized and dissipated by the heat. After ignition, the meteor becomes dark, and reaches the ground without showing any signs of dissipation. A vitrified coating is occasionally seen on the meteorite, but nothing like a general fusion, nothing to indicate in any way an approach towards entire vaporization. No lessening of the velocity is seen, and none can be proved; because gravity is hastening the meteor downward, counteracting, and perhaps more than counteracting, the retardation

by friction. This is especially true when the meteor is seen to fall perpendicularly, or nearly so, as it often does. But meteors have been known to fly a thousand miles, and move nearly horizontally through the upper region of the air, and, if their path keeps them up there, they shine brightly through their entire course. Neither do they show in all this distance any loss of velocity, which they should do if friction alone be the igniting cause.

A very large meteor, on July 20th, 1850, passed over the northern portion of the United States for a distance of 1,300 miles, coming from behind the clouds westward of Lake Michigan, and passing out of view south-east of Nantucket, over the Atlantic ocean, without seeming to become extinct. It was seen from several hundred miles on both sides of its path, and its elevation was calculated to have been 120 miles over Lake Michigan and 41 miles over Rhode Island. Many accounts of its appearance were collected; and these were discussed by Professor J. H. Coffin, LL.D., of Lafayette College, in a valuable paper published in the "Smithsonian Contributions," vol. xvii. A meteor which appeared August 18, 1783, was described by Dr. Blagden as "a luminous ball, leaving a train behind, and yielding a prodigious light." It appeared first over the sea north-west from the Shetland and Hebrides Islands, and, passing over Scotland and England, was last heard from over the continent, traversing at least 1,000 miles in its luminous course. Its height was calculated to have been "about 57 or 60 miles." (See Dr. Phipson's work on Meteors, p. 19.) The continued blazing appearance of the meteors throughout their courses of 1,000 and 1,300 miles, while keeping high up in the air, is very significant, especially when contrasted with such instances as the following, where the meteors are suddenly extinguished when coming straight downwards in the dense air. A meteor, as brilliant as the sun, and appearing nearly as large, was seen November 15, 1859, at half past nine o'clock, A.M. From New York it was southward, and from Washington it was eastward. Its course was nearly perpendicular, and it must have fallen near the mouth of the Delaware Bay. Its height, when first seen, was 120 miles; and, as it shot rapidly downward, it became extinct six or eight miles above the earth's surface. If the stone was red hot, why did it not remain red hot another twinkling of the eye until it reached the earth's surface? The explanation is that the stone was not red nor white hot; but that the compressed air in front of the meteor was incandescent from giving out its latent

heat. Although the friction was greater, there was less latent heat in the dense lower air, and hence the extinction of the light. No decrease of velocity was seen, and none can be estimated, especially with the force of gravity hurrying the meteor downward. I will give but one more instance. Mr. Noyes, of Concord, N.H., writes as follows in the "American Journal of Science," No. 12, 2d series: "Sometime in October, 1840, about two hours after sunset, on a bright, starry evening, I stood in the road, south of my house some six rods, with my arms resting upon the fence, and facing south-west, gazing at the stars. Whilst looking up, almost perpendicularly, I saw a star, or fire-ball, fall a considerable distance, and then become extinct. Some little time after I heard a noise in the air, such as a falling body would make, and immediately after I saw a small body strike upon the top board of the fence, about fifteen feet before me, and glance into the road some six feet, then bounding and rolling along several feet further. I immediately commenced a search," &c. The stone was found; and Professor Silliman, after a careful analysis, pronounced it a true meteorite. Its size is less than two inches in any diameter; and its composition is a tersilicate of magnesia with a simple silicate of soda. In my table silica and magnesia are seen to be the most abundant elements of meteoric stones, though, of course, not of the unoxidized metallic meteorites. But the chief point is the fact that it came down perpendicularly, and its light, like that of all other meteors, was extinct before reaching the ground.

Thus, the horizontal and the vertical flights of meteors, when compared together, prove the frictional theory to be wrong. How, then, are we to regard the mathematical calculations in its favor? These have been done by eminent men, — Thomson, Joule, Hardinger, and Reichenbach, — and they cannot be passed by in silence. I will try to show that these gentlemen have neglected important data.

1. They assume the meteor to be one foot in diameter, and a section of 144 square inches to be presented to the air. But we have just read of an incandescent meteor less than two inches in diameter, and hence its section is less than four inches. Between 144 and 4 there is a wide difference, and the number becomes more enormous when we reckon, as we must, the squares of the velocities.

2. In the calculations the meteor is supposed to travel 39 miles in a second. All the particles of air struck in a second yield a

Thirdly, because of the teachings of the spectroscope.

But how has our solar system been so constituted that here on our planet there are sixty-three elements always oxidized, while in the outer regions we know of only about twenty-one elements, and these are often unoxidized? This leads us to the third part of this paper.

III. *The Process and Order of Creation by which Meteors were formed with but very few Elements, and these few were often left in an Unoxidized Condition.*

To make this process clear, I will show —

First, that the meteors which reach the surface of the earth, stony meteorites and metallic meteorites, come from the region of the solar system, within the ring of the asteroids.

Secondly, that the unoxidized meteors, which burn and leave their phosphorescent and thin ashy trails in the air, come mostly, probably altogether, from the more distant regions of the solar system, beyond the ring of the asteroids.

Thirdly, that the meteors with visible trails were left unoxidized because, at the period of their creation, the simple element oxygen had not yet been formed, and therefore that the era of the creation of oxygen, as well as of many other elements, was not before the creation of the ring of the asteroids.

First, the following are the evidences that the meteorites which reach the surface of the earth come from within the ring of the asteroids.

(*a.*) Their density. The matter of the solar system beyond the ring of the asteroids formed very rare and light bodies, as we see in Neptune, Uranus, Saturn, and Jupiter, and their satellites. Compared with water, the densities of the planets are as follows: —

Mercury	6.71	Jupiter	1.82
Venus	5.11	Saturn	.76
Earth	5.44	Uranus	.97
Mars	5.21	Neptune	.76

Here it is plain that the four outer planets differ from the four inner in so great a degree as to prove that these two sets of celestial bodies are composed of very different materials. For other comparisons, never before given, on different points between these two sets of planets, see my paper on "The Four Great Eras

in Modern Astronomy," in these "Proceedings," and also "The Origin of the Stars," sections 25 and 30. The densities of the meteorites vary from 1.97 to 7. Generally they are about like the density of the earth, which shows that they belong to the inner class of planets. It is most unscientific to suppose that matter in the outer region of the solar system should condense into light bodies when forming planets and satellites, and into heavy bodies when forming meteorites. On the contrary, when we consider the great pressure of the materials upon themselves in the large outer planets, their immense force of condensation, we must believe that those large planets are denser than the small meteors of that region, the same as the earth is denser than the moon, and Jupiter is denser than his satellites. The rare meteors from that outer region I shall show are those which burn in our atmosphere and never reach the ground except as gas or invisible powder.

(*b.*) The nature of the elements forming meteors, and also those forming our earth, could not, by any possible combination, form such rare bodies as the four outer planets. Therefore, in the process of creation by nebular condensation, the meteorites could not have been formed in those outer regions. The outer planets are solid bodies; and, by the views of the solid prominences on Jupiter and Saturn, the times of their rotations have been determined. But meteoric and terrestrial elements cannot, by the laws of chemical combination, form such light solids. All earthy inorganic solids are much heavier than water. Even our light gases, oxygen, hydrogen, nitrogen, and chlorine, combine among themselves to form solids more dense than the outer planets. Chlorine, hydrogen, and nitrogen unite to form the solid sal-ammoniac, or hydrochlorate of ammonia. Oxygen, nitrogen, and hydrogen unite to form the solid nitrate of ammonia. Both these solids are denser than the four outer planets. Oxygen and hydrogen unite to form water, which, as solid ice, is denser than Saturn, Uranus, and Neptune. It is a little lighter than Jupiter, but this cannot be Jupiter's composition. I need not occupy space to show that a great and beautiful globe, 88,000 miles in diameter, doubtless the abode of high intelligence, cannot be composed mainly of ice. Thus we see that neither the elements of meteorites, nor even those of our earth, can form bodies like the four outer planets. Hence we may conclude that such elements do not form small meteorites in those outer regions.

(*c.*) Still other reasons prove that the four outer planets are

Height in miles. n being = number terms of this series. a being = 3.43. na.	Number of volumes corresponding to 1 volume at the surface of the earth. 2^n.	Number of degrees of latent heat. $144\,(2^n-1)$.	Latent heat in 1 volume to nearest degree. $144\left(\frac{2^n-1}{2^n}\right)$	Number of grains of air in cylinder 1 mile long and 1 foot in diameter. Weight at surface of the earth = 2342847 grains = 334.69 pounds avoirdupois.
3.43	2	144	72	1171424
6.86	4	432	108	585712
10.29	8	1008	126	292856
13.72	16	2160	135	146428
17.15	32	4464	139	73214
20.58	64	9072	142	36607
24.01	128	18288	143	18303
27.44	256	36720	143	9152
30.87	512	73584	144	4576
34.30	1024	147312	144	2288
37.73	2048	294768	144	1144
41.16	4096	589680	144	572
44.59	8192	1179504	144	286
48.02	16384	2359152	144	143
51.45	32768	4718448	144	72
54.88	65536	9437040	144	36
58.31	131072	18874224	144	18
61.74	262144	37748592	144	9
65.17	524288	75497328	144	4
68.60	1048576	150994800	144	2
102.90	1073741824	154618822512	144	$\frac{1}{512}$
137.20	1099511627776	158329674399600	144	$\frac{1}{524288}$
171.50	1125899906842624	162129586585337712	144	$\frac{1}{536870912}$
205.80	1152921504606846976	166020696663385964400	144	$\frac{1}{549755813888}$

This table shows the *capacity* of the air for latent heat to be truly wonderful. And the theory is that heat, at these very high degrees, becomes sensible when the air is compressed in front of a meteor. The heat of the meteor, therefore, is not primarily in the meteor itself, but in the air in its front. This air, by its extreme intensity of heat is incandescent, and it burns off the outer layers of the meteor. Mr. Marsh supposes that layer after layer is thus vaporized until the meteoric stone or the metallic mass is all consumed; except in a few cases where the remnants reach the ground. But these meteoric stones and metallic masses which reach the ground are indeed often glazed on their surfaces, but they exhibit no signs

of being the mere cores, the last remains, of much larger vaporized bodies. On the contrary, I have tried to prove that, when meteors are consumed at great heights, it is by combustion; a real chemical combination of their elements with the oxygen of the atmosphere.

But another and greater defect of the theory is that it takes no cognizance of the difference between the *capacity* of the air for latent heat, and the actual amount of heat in the extremely rarefied air. The actual amount of heat in a given volume of air, whether it be latent or sensible, is always a constant quantity, unless additions be made from without. Latent heat is really the conversion of sensible heat into quite another force, that of repulsion. But in this conversion the same amount of force is conserved. If the air be vastly expanded, the repulsion is developed at the expense of the sensible heat; and the consequence is that the *temperature* of the air is lowered just in proportion as the expansion, or repulsion, or latent heat is increased. Therefore, if air be so expanded that the repulsion, or latent heat, is numbered by many millions of degrees, then the temperature of that same air is lowered proportionately. And, when by compression these millions of degrees of latent heat are again rendered sensible, they merely raise the extremely low temperature of the air to its condition of sensible heat before the expansion. The hot air of the plains, when it ascends the mountain-tops, becomes icy cold. The sensible heat takes the form of repulsion: it is latent. And when the same air descends on the other side of the mountain to the plains below, that repulsion, or latent heat, is converted back again into precisely the former amount of sensible heat. When the heated air at the equator rises up, it ascends to the top of the atmosphere, according to the generally received doctrine, and rapidly passes to higher latitudes, when it falls and returns to the equator. But, when at the top of the atmosphere, its temperature must be lowered to correspond with all Marsh's figures of latent heat; and, when the same air descends to the earth's surface in higher latitudes, its latent heat raises the extremely low temperature until the amount of sensible heat is the same again as it was at the equator, minus what was lost by radiation into interstellar space. Therefore, if the generally received ideas of the constitution of the earth's atmosphere be true, Poisson's theory and Marsh's demonstration [illegible] luminosity to meteors. The latter [illegible] of 200 miles the

air has an almost infinite capacity for heat in its latent state, but he has not shown that at that height the actual amount of heat, latent and sensible added together, is any greater than down at the ground.

But a new atmospheric theory has been given to the world by M. Quetelet, *Directeur de l'Observatoire Royal de Belgique*, in his work "*Sur la Physique du Globe*," published in 1861. He supposes that the *unstable* portions of the atmosphere rise at the warm, and fall at the cold, latitudes, forming but a very thin stratum; but that above this, up to about 200 miles, there is a *stable* region of the atmosphere, very rare and without any aerial currents. Physicists generally seem to have come to the conclusion that the atmosphere rises to the height of 200 or more miles, on account of the luminosity of meteors at such lofty altitudes. Two questions now arise;—first, Does M. Quetelet give satisfactory proofs of the existence of this stable region of atmosphere? and, second, Is it charged with heat, both sensible and latent, so as to impart luminosity to meteors? I have not seen his book, but it is reviewed by two critics in "The American Journal of Science," January, 1863. The friendly critic simply delineates the theory, without intimating that it is supported by proofs; the adverse critic, with the signature S.,—Professor Sullivan, the editor, we suppose,—writes of "these novel ideas of the constitution of the atmosphere, unsupported as they are by experiment, and in conflict with long-established laws;" and again, "views which seem to us unsustained either by fact or sound philosophy." If any trust is to be placed in an adverse criticism, a rather venturesome step, we may suppose that Quetelet put forth his views as a mere theory without a demonstration in its favor. Indeed, such a demonstration was then impossible; for Marsh's tables had not yet been constructed. Neither did Mr. Marsh say aught to controvert or remove these adverse criticisms, then before him, against a theory which is absolutely essential to the truth of his own theory of the luminosity of meteors.

But I am happy in announcing, first, that Quetelet's theory of a lofty stable atmosphere is susceptible of absolute proof; and, secondly, that its temperature cannot be *permanently* lowered to the extreme points caused by the abstraction of sensible heat in order to supply the latent heat of Marsh's tables. The proofs of these two propositions appear in this way.

First. In the beginning of our planet's history, when it was all

incandescent, the atmosphere had a very high temperature. As the solid globe cooled, the atmosphere also cooled, but the temperature, even in its highest and rarest region, never went below its present standard of sensible heat. Consequently, it must possess all the latent heat indicated by the tables of Marsh, without any excessively low temperature to counterbalance that latent heat.

Secondly. Without going back to the primitive history of our globe, the same result must be wrought out by present laws. We may suppose all the air heated to its mean temperature, and compressed to within a few miles of the ground. Then if this pressure were removed, it must mount up about 200 miles, and the latent heat of the upper strata must equal the tables of Marsh, and their temperature, to correspond, must be inconceivably low. But this low temperature of the upper air would soon be raised by radiation from the earth, and from interstellar space. This radiation would be very rapid, because radiation is always the more rapid in proportion to the extreme contrasts of temperature.

Thirdly. The same result would take place to-day in any body of air at the equator which should rise up 200 miles by any means whatever, say atmospheric currents. Then would occur the abundant latent heat, and then the extremely low corresponding temperature; and then, before the body of air could travel to a high latitude to descend, its low temperature would be rapidly raised by radiation, as in the case before supposed.

But the great fact in all these three cases would be this. All the upper strata above thirty or forty miles could never come down. The upper 170 miles would necessarily possess millions of degrees of latent heat, and its sensible heat would be abundant from radiation or from its primitive store. Then if aerial currents, or atmospheric commotions of any kind, should bring those strata any distance down, they would instantly, on account of increased pressure, give out sensible heat, and thereby expand and rise up again. The fact of their being once surcharged with so much heat would keep them up for ever. I can think of no way for those upper strata to come down. At the elevation of thirty miles, the latent heat amounts to 73,000 degrees. And a much less degree of heat must be enough to retain those strata safely in their eternal home.

Therefore the atmospheric theory of Quetelet must be true. Poisson's theory of the luminosity of meteors by latent heat is also true. The establishment of both these theories is mainly due to

1	2	3	4	5	6	7	8
Juvenas	1821	June 18	12	49	6	10	12
North America	1827	May 22	15	89	22	.7	4
Cape Gd. Hope	1838	October 13	19	30	22	1	2
Brabant	1840	June 12	14	20	15	2	4
Utrecht	1843	June 2	16	39	24	1	2
Nordhausen	1843	September 16	15	33	26	2	3
Hungary	1857	April	16	34	22	.6	5
Transylvania	1857	October 10	13	36	23	trace	.2
Hungary	1858	May 19	14	41	27	.8	2
Louvain	1863	December 7	12	37	24	2	3
Orgueil	1864	May 14	17	26	17	1	1

It is wonderful how many of the twenty-one meteoric elements are often contained in the same small stone; in one case as many as nineteen. Besides the above, it is instructive to note the Braunau meteorite, which fell July 14th, 1847. The number of its elements is fourteen, *all unoxidized;* they are as follows: phosphorus, sulphur, carbon, silicon, chlorine, magnesium, calcium, arsenic, manganese, cobalt, chromium, copper, nickel, iron. A very small meteorite, described by Professor Shepard, weighed only half-an-ounce. It was round, and slightly pear-shaped, and contained seven or eight elements, all unoxidized, as follows: "sulphur, carbon, cobalt, tin, nickel, copper, iron, and possibly chromium." How wonderful! Here is a meteor with the weight only of an ordinary letter we send to the post-office, and yet it contains seven or eight elements! How thoroughly do all these facts show the mixture to have been! The same truth is further proved by the way the elements are associated. In some meteorites the unoxidized portions are seen as small specks, often merely microscopic; in others these specks are seen larger; in others, still larger; and so on until the unoxidized portion is the larger part of the mass, and at length it forms the entire mass. All this is in conformity with a well-known chemical law, that the more easily oxidizable elements combine first with the oxygen, and when they are satisfied then the oxygen combines with those less easily oxidizable. In this way the copper on the bottom of a ship is preserved from rust or oxidation by fastening on the copper small pieces of a more easily oxidizable metal: these keep up the oxidizing process, and the copper is saved. In the meteorites, therefore, it was conformable to law that some elements should be oxidized before others; but if the oxygen had then existed in sufficient amount, all the elements would have been oxidized.

The above table exhibits the further important fact that, at the period of the formation of the meteorites, other elements besides oxygen had not yet been created in the same proportions as they have since been created in our earth. The magnesia, for instance, existed then in amounts nearly as large as silica, and far in excess of lime. In our earth it is now far less plentiful than lime. The iron also was in great excess as the oxygen was deficient.

These facts about the proportionate amounts of the elements then created are of the same order as the still greater fact, that about forty of our terrestrial elements had not then been created. Had all the elements of our earth been then created, doubtless in that thorough commingling of elements we should have found them all, or nearly all, in the meteorites; because thousands of meteorites have been sent down as specimens to inform us of the elements then existing, and showing us thereby the great and sublime history of creation.

All these numerous facts lead us to believe that the simple chemical elements — mere modifications of some original form of matter — have been formed successively in the process of nebular condensation. At first, in the outer regions of the solar system, they were very few and very light. Then more and more were brought into being, of a denser constitution, both in the general solar and in the several planetary nebulæ. The means by which they were created — the physical forces — and the proofs of the process, I have dwelt on at length in "The Origin of the Stars," sections 13th and 6th. At present I can simply point out how this view explains the large collection of facts in this paper.

1. When the solar nebula was so expanded as to include the orbits of the outer planets, it must have been inconceivably rare; and at that period, accordingly, the rarer elements and the rarer planets were created. Neptune, Uranus, and Saturn cannot possibly be composed of such elements in general as those of our globe. Still, such rare metals as are lighter than water — sodium, lithium, and potassium — may be there combined with some other gases peculiar to those planets, but not with oxygen and hydrogen. Metallic potassium, when combining with oxygen and hydrogen to form the dry solid hydrate of potassa, undergoes a condensation, such that a cubic space which holds 430 atoms of metallic potassium will then hold 700 atoms of potassium, 700 atoms of hydrogen, and 1,400 atoms of oxygen: 2,800 atoms in all. An enormous condensation, say from 430 ounces to 2,800 ounces in the same

of a current to the top of the stable atmosphere, 200 miles at least, and whose limit is not yet known ?

I came to the conclusion that this southward stream of electricity, the aurora borealis, is a continuous daily stream, in this way. In passing, at different times, from Philadelphia to Canada, and in spending the summer vacations at different places in those cool provinces, I observed that the auroral lights were more frequent in Montreal than in Philadelphia; that at Quebec they were more frequent than in Montreal; and that at Grand Bay, sixty miles up the Saguenay River, they were more frequent than at Quebec. They were so frequent at Grand Bay and Chicoutimi, 120 miles north of Quebec, from my own observations and the testimony of residents there, that I judged they must be nightly a few degrees further north. By making researches among the reports of travellers and temporary residents in high northern latitudes, I found this to be true. In this way the theory for the necessity of a constant daily flow of electricity southward, over the top of the stable atmosphere, perfectly agreed with actual observation, by several competent persons, of such daily flows. This result I embodied in a paper on the "Auroral Display of April, 1869," published in the "Proceedings of the Academy of Natural Sciences of Philadelphia," in August, 1869.

Professor Loomis, of Yale College, had published in the "American Journal of Science," and elsewhere at different times during ten years previously, a circumpolar map with colored zones showing the frequency of the aurora borealis, at different northern latitudes; and the colored zone of greatest frequency gave, on an average, eighty auroral displays per annum. I mention his name because he is a prominent writer on the aurora borealis, and a good representative of the doctrine formerly current. In my paper, I pointed out the error of himself and of many others; and, just one year afterwards, — at the meeting of this Association in Troy, 1870, — I was happy to see, in an elaborate paper on the aurora, that Professor Loomis had adopted my views of daily, or rather nightly, displays. His paper was published, the next month, in the "American Journal of Science." Whether his new views had been derived from my own, or whether he had come to the same conclusion independently, he did not say, as he did not refer to the change of his opinions.

In beginning this paper on the long persistence of meteoric trails, I spoke of the discussion as altogether new to science. But

I did not then think of treating fully of more than one of the theories of meteoric luminosity, — that of combustion.

In describing the Four Great Eras of Modern Astronomy, I pointed out the new and wide fields of research opened by this fourth era. This paper on Meteors is an illustration of these views; for its principal new truths flow mainly from a consideration of the nebular theory.

II. PHYSICS AND CHEMISTRY.

1. A Discussion on Perturbation of Forces. By James D. Warner, of Brooklyn, N. Y.

By Perturbation of Forces is meant a disturbance of the static forces (the tensions and diatensions) of matter, by which a mass, a molecule, or an atom (ultimate) is held *in equilibrio* in space, either at rest or in some regular path.

A material substance is found capable of yielding or imparting any motion which it may have, and capable of receiving motion. The first is its "Power of Activity," or its capability of exerting power or energy; the other is its "Power of Passivity," or its capability of being impressed by power or energy.

An "Exertion of Power" is necessary to produce an effect or motion, or change of motion. The cause is a Force, or Forces; the effect is Motion. Forces always produce motion, unless there is a balance of antagonistic forces, in which case we have the static or equilibrated state of matter; but this may still be treated as motion by considering it the algebraic zero of motion.

No effect is performed or executed in an instant; hence the element of Time must necessarily be considered. In other words, to give birth to Exertions of Powers, or Energies, and render them living or effective powers or energies, intervals of time must be considered.

Corollary: Matter cannot be continuous, or else all matter would

either move instantaneously or not at all, by an Exertion of Power.

Since matter is not continuous, there is an interval of time for the transference of motion from atom to atom: this is a constant quantity for equal distances, or at least constant for each element in its several states or conditions.

Since motion is uniformly progressive, there must be, at the commencement of transference from one atom to the next, a stop or stay in the motion before the ultimate becomes fully impressed by the force and moves. This constitutes a force of resistance, and is called "Inertia," or "Force of Inertia." As motion is communicated from ultimate to ultimate, all bodies develop Inertia in proportion to their mass.

The exertion of power must also have *intensity* as well as duration.

Force, in causing motion, is modified by the mass upon which the energy is exerted, and each atom must store an equal quantity (unless there is a distortion of the mass), and the force will exhibit itself in the mass aggregatively as momentum which is measured by the effect it will produce. It is also modified in its action whenever the *velocity* of the motion is in excess of the velocity of the constant in which motion is capable of being communicated from atom to atom.

The direction in which a force acts, in its tension or diatension (the minus of tension), has always been considered to be coincident with the resultant or direction of motion, in case motion is produced. Between the centres of gravity of masses, the lines of forces or tensions may not be in straight lines, but be curvilinear, and such that the axes of the curves will be straight lines between the centres of gravity. The Magnetic lines of force certainly seem to be curvilinear, as the arrangement of iron filings between the poles seems to indicate. Tyndall and Faraday have both written about the weaker lines of force between the magnetic poles. And their experiments on magnetism and diamagnetism show that these lines of force are varied by the substance, shape, and structure of the substance. Again, Faraday alludes to these lines of tensions or forces when he says: "That we know no more of the physical nature of the electric lines of force than we do of the physical nature of the magnetic lines of force." In the experiment where a whirling coin is placed between the poles of a battery, the whirling must be arrested by the exertion of these forces, and

not, as supposed, by the flow of an assumed invisible and intangible current. Again, the resistance by moving a saw between these poles is the action of these forces, as the current (which is assumed) would be so nearly immaterial as to be incapable of producing so much effect as to be perceptibly felt. The Induced Currents, and the silent yet distant passage to points of electricity, are actions in directive lines of forces. Crystallization is effected by these lines of force. Polarization of Light is also caused by the directive or elective lines of force; and these elective lines of force may be interfered with by other forces, as exhibited in the passage of light through heated or unannealed glass. In Chemistry, selection, combination, reaction, allotropism, active and passive states, may need for a better understanding a knowledge of the various variations in the lines of force or tensions. Difference of colors and action of light may need for a complete explanation the resolution of the lines of force.

Attraction and Repulsion are opposing physical forces belonging to all substances: assuming that the only line of force coincides with the resultant effect, repulsion cannot be taken as the negative of attraction, or else the common law of attraction, — viz., that the product of the intensity into the square of the distance is always a constant quantity, — holds good when one factor, the intensity, becomes negative, which would be absurd.

Again, from the above law, the great amount of energy displayed in atomic combination can be deduced; but in repulsion at the same distance we may have equally as great energy, and again at many other distances we have little or no repulsion. Some physicists have assumed that there are two classes of elements, one repulsive and the other attractive; but we find by a change of state that there is a change in each of these forces: as there has been no change of elements, this assumption is evidently untenable. There remains, then, no other conclusion but that attraction and repulsion are two distinct forces, having distinct opposing lines of direction; or if these lines of forces or tensions of attraction and repulsion are an exhibition of but one general force, then they are of such complexity as to give reversals of effects at various distances.

All the lines of force or tension in a homogeneous medium are affected by any disturbance, but those whose directions coincide most nearly with the direction of the motion causing disturbance will be most affected; and the more rapid the motion, the greater will be this difference. Hence, as a result, the most sensible motion,

or the greatest effect, will continue in straight lines in the same direction as the motion. With extreme velocity, the lateral effect is sensibly lost.

Lines of force not being effects may change instantly in direction.

If a material substance be moved in any homogeneous medium, the direction of all the lines of force acting upon it will be changed; when moved with a nearly infinite velocity, the substance will not be affected by variations in energy on account of its change of position, but the original assumed forces will arrest the motion and cause it to return; having acquired a momentum, it will pass the original starting-point; and now, having the same conditions as were first assumed, it will have a similar movement, and this will continue, and we will obtain a continuous vibratory motion.

The effect of this movement upon ultimates will be such as to change the forces acting upon surrounding ultimates: these ultimates will thus become an agent for communication of motion. This will give us vibrations producing *Heat.*

If the variations in these lines of force be so nearly instantaneous as to give no translation of the ultimate, there will yet be a variation in the direction of the lines of the forces by which the surrounding ultimates hold this ultimate equilibrated; and these, for the same reason, will act upon others, and thus we will have a thrill or tremor without translation, giving us the phenomenon of *Light.*

Whenever the velocity is such as to allow a transference of motion from atom to atom, we will have the phenomenon of *Sound.*

Light is only made known to us by the eye, which, by its peculiar structure, changes the directions of the lines of force or tensions so that several of the alternate signs of the perturbations are changed, and this increases the length of time of action upon the nerves of the eye, so as to produce a vibration of atoms. The eye thus becomes an instrument, measuring the vibrations not according to actual measurement, but proportionally. It may be for the same reason — that is, of degrading the motion — that heat of great intensity is found to be innocuous in its effect upon the eye, as shown by late experiments of Tyndall. The proportional degradation of the actinic rays is such as will not bring them within the scope of sensibility.

It will be seen that I do not ascribe to light transverse vibrations. I see no reason for assuming them to be transverse, except that a possible explanation of polarized light may be given. Polar-

ized light, I assume to be caused by interior reflection upon the facets of the innumerable atoms of various crystals by which the direction of the lines of force are so changed that the eye manipulates all the rays whose directions of lines of force coincide with axis X (in Cartesian co-ordinates), but does not those coinciding with axis Y. Rotating these axes upon axis Z, the eye will manipulate those of Y, but not those of X.

The above are a few suggestions for the purpose of arriving at a theory of perturbations more consistent with the laws of Mechanics than the present theory of perturbations producing Light, Heat, and Sound. I refer more particularly to those parts of the theory which assert that a *substance* called ether is supposed to exist; also, that the perturbations producing light are transverse; and, also, that there is transmission without retardation or interference only when the waves are of equal length.

First, then, in regard to *ether*. No physicist has undertaken to explain what ether is without having been compelled to ascribe to it properties varying entirely from all known substances. For instance, its density. Some have supposed it extremely rare, and that it permeates all other substances. If so, how can it acquire so much momentum as to communicate its motion to such great distances as those to which we sometimes find light has been transmitted? Others suppose, in order to overcome this objection, that it is very dense. If so, why is it not retarded by other substances, and the vibrations changed to vibrations of heat?

Second, in regard to *transverse vibrations*. How are we to conceive the atoms to pass through the axis without interfering with each other? Also the greater motion being in a lateral direction or transverse to the axis of motion or vector I, it must become direct motion in the plane of the versor i; or, supposing it to have an advance motion in the direction of vector I, the resultant effect would be direct motion coinciding in direction with the surface of a cone of one nappe, with axis vector I, and opening in a positive direction.

Third, in regard to *transmission*. The theory of transmission has been assumed to correspond with the rippling of water when the surface has been disturbed. The surface atoms are not in an equilibrated state in regard to the tensive forces. To trace the effects, we should go below the waves; also any heaping up of the atoms of a mobile substance causes this portion to preponderate in weight over the lesser elevated surrounding portions. To

obtain equilibrium, the elevated portion will descend; in descending, the atoms underneath are pushed out laterally, and wedge up those above mentioned, which were the lesser elevated; having motion, they will acquire momentum, which will carry all beyond their points of equilibrium, and this will produce results similar to the condition first assumed, and this again a similar disturbance with similar results and continuance. The paths of the surface atoms will be in perpendicular lines. Those underneath will be in downward and outward curves from these lines, as they must move and communicate motion to adjacent atoms, so as to cause displacement with a certain constant velocity for equal times; and as the force of gravity gives perpendicular motion according to a certain constant law, it follows that as the perpendicular paths of the surface atoms shorten, their divergence from the perpendicular is in a larger curve, and the length of these curves is greater. Hence, as the amplitude decreases, the waves lengthen. This does not correspond with the known facts relating to light, heat, and sound.

Also in regard to interference of waves of different lengths, when any two waves coincide (in conjunction or opposition), there must be a resultant as much when they are of different lengths as if they were of equal lengths. This resultant, when once formed, is irresolvable into its original components. The senses may resolve them into metrical factors according to some systematic law, which is the result of education.

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2. THE LAW OF ELECTRIC CURRENTS. By E. B. ELLIOTT, of Washington, D. C.

(Abstract.)

THE law of the action of elements of electric currents, as commonly given, assumed that the action was invariably in the direction of the ideal line which connects the elements. This view Mr. Elliott deemed too limited and incomplete, the more complete statement of the law demanding action in various directions in space, according to the varying relative directions of the elements.

The restricted law, as ordinarily given, was inconsistent with the generally acknowledged principle of the conservation of force, whereas the completed statement now given was in full accord with this principle.

The incompleteness of the law of electric action, as hitherto given and known as that of Ampère, had been asserted by the eminent English electrician, Faraday, who was obliged to superadd to it another, which he called the law of angular forces. The complete law, as now proposed, embraced in one simple expression all that was essential to the incomplete law of Ampère, and the supplemental law of Faraday.

The paper was illustrated by diagrams and analytical formulæ.

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3. On some Improvements in the Reflecting Telescope. By J. A. Hill, of Greencastle, Indiana.

It may not be amiss briefly to refer to a few points in the past history of reflecting telescopes, for the purpose of showing the gradual process of development which they have undergone, and the many obstacles which have presented themselves from time to time, in the efforts to increase the power and utility of such instruments; and also to show more clearly the relationship sustained by the plan which we now propose to the various others which have preceded it.

From the time when James Gregory and Sir Isaac Newton proposed the arrangements of mirrors and lenses, which have since borne their names, to the present time, the success has indeed been most gratifying: as witness the marked improvements which have taken place under the direction of Short, Mudge, Edwards, Herschel, Rosse, and others; the one or the other of these forms, or their various modifications, taking precedence in popular favor accordingly as they were adopted and improved from time to time by the ingenious men just mentioned.

But to the elder Herschel we are indebted for the production of

the first telescopes which, passing all previous limits, were made of seven, ten, twenty, and finally of forty, feet focal length.

Yet this latter instrument was liable to two important objections, viz.: first, the large and very heavy tube to contain speculum, eye-piece, &c., requiring a very complex and unwieldy structure to give the proper support and motions to the tube, and also to enable the observer to follow the eye-piece from point to point, this being placed at the upper end of the tube in this construction; and, second, the want of reflective power in the speculum. With the kind of mould then in use it was not possible to successfully cast specula, of true speculum metal, of any considerable size; hence the metal used in this large reflector was inferior in quality, having less reflective power and more liable to tarnish than that employed in the smaller and more perfect instruments.

Here, then, we find the limit was reached at that time in size, or rather, should we not say, was exceeded, considering the inferior quality of this monster telescope.

Your minds will now at once revert to the subsequent labors of that ingenious nobleman, the Earl of Rosse, one of the main results of whose numerous experiments was the construction of a mould, by means of which he cast successfully, and with comparative ease, mirrors of three and even six feet in diameter. These mirrors were composed of copper and tin united in their atomic proportions, which yielded, when ground and polished, a reflective surface of the most brilliant and permanent character. With some experience in the use of this mould, and taking into consideration the principles upon which it acts, I have no doubt that specula can be produced of any required size, with more certainty and far less trouble than was experienced in casting comparatively small ones on the old plan.

But when he came to mount for use his six-foot speculum, with a focal length of fifty-six feet, the speculum and box, together with the accompanying tube, weighing about fifteen tons, Lord Rosse found himself compelled to limit the motions greatly, there being only 15° of azimuth motion, thus largely diminishing its utility in various ways.

Still, although so circumscribed in motion, a necessity yet existed for an immense amount of mechanical appliances, such as walls, counterpoises, arcs, chains and windlass, movable galleries, &c., &c., to direct the tube and enable the observer to follow it, — this telescope, like Herschel's, being built on the "Le Mairean"

or "front view" form; requiring the observer to be suspended in the air at a height of nearly sixty feet when looking at the zenith.

The plan suggested in this paper is an attempt to obviate this only remaining difficulty so far as construction is concerned, and to enable us to build telescopes without such limits, and of any required size, and which can be used with more ease and comfort, no matter how large, than any yet made, either reflectors or refractors.

To accomplish this, I propose to use two mirrors, operating substantially as shown in Fig. 1. *A* represents a mirror circular in form, and ground on one surface to such concavity as to give the required focal length. *B* represents another mirror, oval in shape, and with the reflecting surface plane. The lesser diameter of this mirror should be equal to that of the concave one, and the larger diameter should be to the smaller as 5 or 6 to 4.

In the centre of this plane mirror is an oval hole, *O*, of such size as to allow the passage of the cone of rays thrown from the concave surface, *D;* the image being formed behind this oval mirror at *K*, and the eye-piece being applied as in the Gregorian and Cassegrainian styles.

The concave mirror is placed in a vertical position, so that the axis of said mirror shall coincide with a line running horizontally north and south, as *CC* in the figure. Opposite to this, and a little nearer to it than its focal length, is placed the oval mirror, which has two motions, one parallel to or coinciding with an imaginary axis, *H H*, passing through its lesser diameter, and the other about a hollow axis placed at right angles to the former axis, and whose motion is made around the line *CC* as a centre. In this hollow axis the eye-piece is placed.

Parallel rays from an object, *F*, falling on to the plane mirror, *B*, will be reflected on to the concave surface, *D*, and from thence through the hole, *O*, in the plane mirror, forming an image at *K*, which, being magnified by the eye-piece at *S*, will be seen by the eye at *E*.

Now, by moving the plane mirror around the line *H H*, it will be readily seen that any object from the zenith, *M*, to the horizon, *N*, may be viewed, and, by moving it around the line *CC* running north and south, any object between the eastern and western horizon may be viewed; thus embracing one-half of the visible heavens. These two motions correspond to the altitude and azimuth motions

of other instruments. It will be observed that the eye remains in one position, looking in one direction all the time, wherever the object may be situated within those limits.

Now, by reversing the mirrors and looking in the direction of the same line, but in an opposite direction, the other half of the heavens can be seen.

To convert this instrument into an equatorial, we have only to incline the mirrors, preserving their relative position, so that the imaginary line joining their centres shall be parallel to the axis of the earth; then, by moving the oval speculum about this line as a centre, any sidereal object can be followed by the one motion.

Fig. 2 represents a small instrument mounted as an equatorial. *G* is the stand or pedestal made of any suitable material, upon the top of which is fastened the bed-plate, *R R*, at a suitable inclination, by the bolts *b b*. At each end of this is an upright, *S S*, into which the axes of the telescope are laid. *A* is a shorter box with concave reflector; *T* is one of two bars fastened on to opposite sides of box *A*. Between these bars at the opposite ends is placed the plane mirror *B*. Back of this the two bars are united by a cross piece, into which the hollow axis with eye-piece is placed. The mirror is fastened at any inclination by the thumb-screw *I*. This is easily reversed by lifting it out of its bearings; and when not in use may be kept in a suitable box, the stand and bed-plate being permanently fixed in their positions.

Fig. 3 shows an instrument of a larger size. At either end of the telescope a small room or observatory, *A A*, is seen, through the walls of which the hollow axis with the eye-piece passes, the observer being on the inside of the room. By means of suitable mechanical contrivances the proper motions are communicated from the inside to the mirror, *C*, thus enabling the astronomer to remain seated in *one* position, looking in *one* direction, and *entirely protected* from *cold*, *fatigue*, *night air*, &c. A very simple contrivance applied under the arms, *T*, will serve to sustain the weight, and also to reverse the instrument when required. This *telescope* also offers *unusual facilities* for *studying*, *drawing*, *mapping*, or *photographing* the heavenly bodies. Any object which will admit of it may easily be photographed by darkening the room and placing a plate of the right size to receive the image properly prepared on a movable screen, the size of the image being regulated by the distance from the eye-piece. This arrangement would enable

many persons to contemplate some of the celestial bodies, such as the *sun*, *moon*, &c., at the *same time*.

To construct an instrument on this plan, of, say, twelve or fifteen feet diameter, and 150 or 200 feet focal length, let the ground be first levelled, and then the towers built at a suitable distance apart. Between these a double railroad track should be laid, the tracks running parallel to each other from north to south, and uniting in one curve at either end. The mirrors would be mounted separately on solid structures, movable on wheels, and thus would be easily reversible.

Differing as this does from all other constructions of telescopes, it will readily appear that a *great focal length is not objectionable*, it being as *easy to handle a mirror of* 1,000 *feet focal length as one of the same size of fifty feet focus*.

To convert such an instrument into an equatorial, select a piece of ground sloping to the south, grade to the exact inclination to give parallelism of the axis of telescope with that of the earth: the towers being built as usual if desired, and the mirrors mounted, the instrument may be used as an equatorial. Fig. 4 is a rough sketch of such an arrangement.

If it is desired to command a view of the whole heavens without reversing the mirrors in the usual manner, I would suggest that both sides of each mirror be used alternately, one side of each being made plane and the other concave.

Thus the concave side of the lower mirror being used with the plane side of the upper one commands the southern heavens from the northern tower, and the plane side of the lower one used with the concave side of the upper commands the northern heavens from the southern tower. Both mirrors in this case must be perforated in the centre. The mirrors, in this instance, may be solidly fixed in their positions.

As it has not been thought necessary to enter into details, either as to the many forms this telescope may assume, or to the great variety of mechanical devices for moving the plane mirror or reversing the two mirrors, which would be adapted to those forms, a few words of comparison with other reflectors is all we shall add.

The tremor, so much complained of in some forms, having small specula supported on the ends of rods, or eye-pieces supported on the ends of long tubes, would be absent here, as the bearings are at each end, near the mirrors.

No tube is used for any size, but arms or bars connecting the

specula may be used in the smaller sizes for convenience of handling, reversing, &c.

In illuminating power, they are equal to all other telescopes having two mirrors, and inferior alone to the "front view" form, but superior to it in having no distortion of the image caused by inclining the mirror in that form, so as to throw the image to the side of the tube.

It is by far the simplest equatorial yet constructed, and the only one in which the line of sight, axis of instrument, and axis of the earth all coincide. Clock-work may be added as in other equatorials, and a simple contrivance can be attached to the plane mirror, when the telescope is not in an equatorial position, which will give it a parallactic motion. This it is not necessary here to describe.

Simplicity of construction will enable these to be made much cheaper than others, especially if Foucault's plan of using glass mirrors be adopted.

One mould would answer for both mirrors, one side being convex and the other plane.

I am impressed with the conviction that for any future enlargement of the boundaries of our observations we must look to the reflecting telescope, as it is impossible to construct refractors at all approaching the size which may be realized for mirrors.

The ratio of the illuminative power of a refractor and reflector of equal aperture is usually considered to be as 8 to 5. Still the Earl of Rosse succeeded in producing mirrors which were considered little, if any, inferior to an achromatic of equal aperture. The plane mirror might be made of blocks of speculum metal fastened on to a common basis, and then ground and polished. Any slight deviation from a perfect figure would only cause a slight distortion, and not spherical aberration, as in the case of concave mirrors.

If telescopes, *far excelling in size and power* any yet made, shall be constructed, it is evident that the *enormous tubes*, with the *vast machinery to give the usual motions to those tubes must be dispensed with.* This arrangement of mirrors does that effectually, and it is doubted whether any other as simple can ever be devised, involving at the same time so many points of convenience and comfort in their use. The remaining difficulties of atmospheric inequalities, &c., are, of course, common to all instruments of any construction, and their discussion is not within the province of this paper.

4. The Daily Motion of a Brick Tower, caused by Solar Heat. By C. G. Rockwood, of Brunswick, Maine.

The observations which form the subject of the following discussion were made during the spring of 1866, in the south tower of the Sheffield Scientific School in New Haven, Conn. This tower was built during the winter of 1865, but was still unfinished in April, 1866, when these observations were commenced, although all the brickwork was completed. The stuccoing of the outside was not finished until June 1; and, during the whole time occupied by the investigation, the presence of the workmen, with scaffoldings, &c., although not vitiating the truth of the results obtained, was a hindrance to that perfect success which might be expected from a repetition of the experiments under the more favorable conditions of a completed tower and more delicate instruments.

The structure in question is a square brick tower, stuccoed on the outside, the exterior surface being much broken up by recessed windows and various architectural adornments. The general plan of the building precluded the use of solid masonry in the tower, which would have been desirable for any structure designed, as was this, to support astronomical instruments. The walls were, however, made unusually heavy; and, in order to have as firm a base as possible for the telescope, the upper story was arched with brick, forming a solid and pretty firm brick floor, upon which now rests the stone pier of an equatorial.

The whole tower is surmounted by a revolving wooden turret. The story below the observatory, and immediately beneath the brick arches, is occupied by the works of the tower clock.

The dimensions of the tower are as follows:—

Side of the square at ground	16½ feet.
" " " top of brickwork	15 "
Thickness of walls at first story	27 inches.
" " " top of brickwork	16 "
" " " where the arches spring	20 "
Height to top of turret	90 feet.
" " brickwork	80 "
" floor of observatory room	75 "

The tower is connected by its north side with the main building for an altitude of about forty-five feet. Projecting from the south

side of the main building, it has its north wall in a line with, and forming part of, the south wall of the building. The whole edifice stands in a position inclined to the meridian, the sides of the building, and consequently those of the tower, having the direction N. 28° 30′ E.

Previous observations elsewhere (*e.g.*, at Bunker Hill Monument) had led to the apprehension that such a tower, besides being subject to tremors communicated from the ground, would have a definite and somewhat regular daily motion, dependent upon the influence of the sun's heat in expanding the materials of which it was composed. The object for which this investigation was undertaken was to ascertain whether this motion would affect the use of the telescope or not.

In order to investigate the motion in the present case, two levels were placed at right angles with each other, upon a flat stone embedded in the brick floor of the observatory room (to avoid any undetermined changes which might affect the woodwork), and their indications were recorded from time to time. Any tipping or motion of the tower would of course change the plane of this floor by the same amount, and would be shown by a corresponding motion of the bubble of one or both of the levels. The levels used were: —

I. The striding level of a small transit instrument, the property of Professor C. S. Lyman. This level, supported by its iron stand, was placed parallel to the *front* of the tower, and therefore approximately east and west. It was read by a scale graduated to hundredths of an inch. Examination with a level-trier gave 1 inch = 39″.37 as the value of its divisions.

II. An unmounted Ertel bubble which rested directly upon the stone, being placed parallel to the *sides* of the tower, and so approximately north and south. It was read by a scale of tenths of an inch, graduated upon the glass, and reading by estimation to hundredths. Professor Lyman had previously determined the value of the divisions of this level at 1 inch = 51″.7, which was adopted in reducing the observations.

The levels were recorded six times during the day, at intervals of about two and a half hours; the first record being between seven and eight A.M., and the last between ten and eleven P.M. The series extended, with some omissions, from April 24th to July 7th; but some of the records being afterward rejected as unreliable, the final results were obtained from the discussion of obser-

vations upon fifty-nine days, included between April 24th and July 2d, 1866. It will be noticed that about one-half of this period was before the stuccoing of the tower was completed; and during about two weeks, from May 15th to June 1st, the tower was partially shaded from the sun by the scaffolding necessary to this work.

A third level placed with the others upon the stone floor, and also the levels of an Altitude and Azimuth Instrument, which was temporarily mounted on a brick pier in the room, were recorded during a part of this time; but, as their results were not employed in the discussion, it is not necessary to notice them farther than to say, that in general they confirmed the indications of the principal levels.

Let us now examine briefly what would be the probable motion of a tower thus situated, and then compare this theoretical result with that given by the recorded level readings.

First: suppose an isolated symmetrical tower of homogeneous material, situated at the equator of the earth, and the sun at the equinox. The diurnal circle of the sun then passes through the east and west points of the horizon and the zenith of the tower. In the morning the heat of the sun's rays would expand the east side of the tower, and cause it to lean toward the *west*. As the sun rose toward the zenith, and warmed equally all parts of the tower, it would gradually return to its mean position. In the afternoon, as the east side lost its heat by radiation, and the west side was warmed by the declining sun, it would lean toward the *east*; and during the night would return again to the mean position. Thus the motion would be back and forth over a straight east and west line.

Again, suppose the same tower situated at the pole. Then, since the sun's rays strike it during the whole twenty-four hours, and always at the same angle, the tower, leaning always from the sun, and always to the same amount, would follow the sun in its diurnal revolution, its top describing a circle about its normal position.

At any station intermediate between the equator and the pole, the figure described by the tower would be neither a straight line nor a circle, but between the two; *i.e.*, an *ellipse*, whose eccentricity diminishes as the latitude of the place increases.

In the case under discussion, the tower is in N. lat. 41° 19′, and the sun was near the summer solstice. The sun therefore rose

about 30° north of the east point, culminated south of the zenith, and set north of west.

The inclination of the tower, being opposite the sun, would be, in the morning south-west and west, at noon nortn, at evening east and south-east, and during the night it might be supposed to return in a straight line to its mean position. Since the sun's rays strike the perpendicular sides of the tower more obliquely at noon than at morning and evening, the northward inclination would be less than the westward or eastward, and the curve described would resemble an ellipse, with its minor axis in the meridian, and probably somewhat flattened on the south.

This tower also is not symmetrical nor isolated. It may be considered as a right parallelopiped, standing with its sides inclined to the meridian, and for half its height joined by one side to a large building, which, so far as any effect of the solar heat is concerned, may be regarded as fixed. One side of the tower being thus firmly held by its connection with the building, any motion *toward* or *from* the building would be simply *checked* or *retarded* without change in direction; while to any motion at right angles to this would be added another element, a motion in *azimuth* or a *twisting* of the tower about a vertical line. A scale was prepared in a distant steeple, and the telescope already mentioned was directed upon it, with a view to determine any such azimuthal change. The observations with this arrangement showed a probable daily change of 8″ or 10″ in azimuth; but the instability of the telescope and other causes so far impaired their value, that it was not thought best to incorporate them in this discussion.

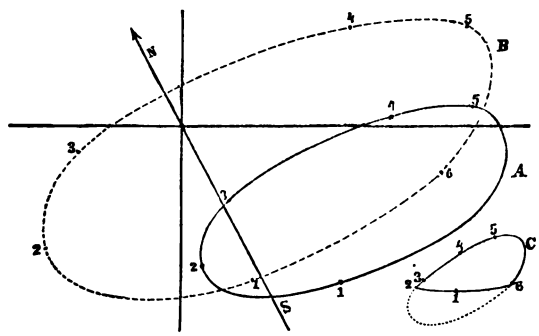
The recorded observations give a series of level-readings at certain hours upon fifty-nine days. The most obvious method of combining them is to take the mean of the readings for all the days, as representing the probable motion of the tower for any one day. Thus combined, the means are as follows, the levels being designated by the numerals I. and II., and the level readings having been reduced to seconds.

Mean Level Readings.

+ East.						
I.	−5″.76	−0″.95	−1″.57	−7″.62	−10″.67	−10″.48
+ North.						
II.	+5″.64	+5″.03	+2″.97	−0″.37	− 0″.78	+ 3″.36

If now we let these numbers [illegible] as and ordinates of a plane curve, referred [illegible] he direction of the

levels, this curve will be the figure described daily by the normal to the plane of the levels or by any vertical line of the tower. It should also be borne in mind that a *south* level reading indicates a *north* inclination of the tower, and *vice versâ ;* therefore, to represent the actual motion of the tower, the signs of the above means have been changed throughout in plotting the curve. The curve thus obtained is the one marked *A* in the figure, the points given by the observations being marked by the numerals 1, 2, 3, &c., in order, beginning with the morning observation. It is seen to be an imperfect ellipse, with a major axis of about 12″ and a minor axis of about 5″, and the minor axis coincides nearly with the meridian. It thus corresponds tolerably with what had been anticipated. But the minor axis of the ellipse is not exactly in the meridian, and the curve is somewhat flattened on the south-



west and north-east. Apparently the connection of the tower with the main building has checked the north and south motion, and so shortened somewhat the extreme ordinates; as we see that, by simply lengthening the ordinates on the north-east and south-west, the curve may be made symmetrical, and its minor axis be brought into the meridian.

But it is evident that, in any thing which depends so directly upon the sun's heat, the average of *all* days will not give a true result. It is necessary to make a distinction between *clear* and *cloudy* days. From the records of the weather, the observations were therefore separated into two classes, — viz., days more than one-half clear and days more than one-half cloudy; and there were found thirty-five of the former and twenty-four of the latter. The level readings of these two classes were then tabulated separately, and the mean readings taken as before, to represent the probable

motion of any one clear day or cloudy day. These tables (which accompany this paper) give for each observation the hour of the day, and the reading of each level, both in inches and in seconds of arc.

The mean readings of the two tables, with the mean times of observation, were as follows:—

Mean Level Readings — Clear Days.

	7h 50m A.M.	10h 33m A.M.	0h 59m P.M.	3h 32m P.M.	5h 58m P.M.	10h 39m P.M.
+ East.						
I.	−2″.72	+4″.79	+3″.52	−5″.96	−10″.17	−9″.33
+ North.						
II.	+5″.52	+4″.48	+1″.08	−3″.55	−3″.86	+1″.61

Mean Level Readings — Cloudy Days.

	7h 47m A.M.	10h 30m A.M.	0h 59m P.M.	3h 33m P.M.	6h 3m P.M.	10h 47m P.M.
+ East.						
I.	−9″.94	−8″.60	−8″.65	−10″.15	−11″.43	−11″.98
+ North.						
II.	+5″.82	+5″.76	+5″.59	+4″.49	+3″.91	+5″.65

These averages, with the signs changed, being made abscissas and ordinates, give the two curves marked *B* and *C*, the observations being indicated by numerals as before.

We see at a glance how necessary to a true result was the separation into two series. The two curves have indeed the same general form, but how different their sizes and positions. For clear days the longer axis is about 17″, while for cloudy days it is not more than 4″. The curve for clear days shows the same shortening of the ordinates that was noticed in *A*, though to hardly so great an amount. But the curve for cloudy days is very much distorted, and no longer resembles an ellipse.

This excessive departure from the normal ellipse cannot be attributed solely to the connection with the main building, for any such retarding effect as has been supposed should be greater when the absolute amount of motion was greater, and therefore should be more evident on the curve for clear days.

An examination of the figure will, however, suggest another, and probably the true explanation. All the points *known* in the curve under consideration, except the one given by the *morning* observation (marked 1), may be found upon a curve nearly similar to the one for clear days. And the distorted position of this point may be accounted for by the supposition (which in fact should not be unexpected), that on a cl[illegible] not affect the

tower *so early in the day* as on a clear day. Consequently, when the effect begins to be perceptible, the sun has already passed the prime vertical so far as to shine very obliquely upon the north-east side of the tower, and therefore the tower inclines but very little to the south-west of its mean position, and the corresponding part of the ellipse is wanting.

Again, the curve for cloudy days lies considerably farther south and east than the other, instead of being concentric with it. As the south side of the tower is the one most affected by the sun's heat, and moreover has nearly twice the free altitude of the north-east side, it might naturally be supposed to expand most under the influence of the sun's rays; and this, combined with the connection of the north-east side with the building, and its inclination to the meridian, would throw the curve for clear days to the north and west of the other, as it is found to be. It is noticeable also that on clear days the tower is thus maintained out of its normal position by a considerable amount.

Still more, the mean inclination of the sun's rays to the vertical lines of the tower at noon, on the days classed as clear, was 21°; and, supposing the intensity of the sun's heat to vary as the sine of the inclination, the minor and major axes of the ellipse should be to each other as sin 21° to sin 90°, or as 35 to 100. Now the minor axis is about 7″; hence the major axis should be from this cause about 22″. It is really about 17″, a discordance which I think cannot be considered great, when it is remembered that the tower, being more or less shaded by trees, &c., could not, even on a clear day, be affected by the sun, until the latter had risen some distance above the true horizon (for which the above proportion is calculated), and that the inclined position of the tower to the meridian would probably also affect this element.

The curve deduced from the observations is thus seen to exhibit a sufficient degree of correspondence with what had been anticipated, from theoretical considerations, to confirm the truth of the reasoning; the departures from the perfect ellipse being no greater than can be ascribed to the unsymmetrical position of the tower, its connection with the main building, and other disturbing causes. In all this discussion the varying powers of absorption, radiation, and conduction of the materials of the tower have been left entirely unnoticed. They would undoubtedly have their place in a complete investigation, but no data were at hand for estimating their influence.

If we may suppose the tower to be equally expanded in all parts of its height, the vertical side would be changed into a uniform curve, as $A\,B$ in the figure; and since the deviation from a vertical is small, the tangent at A would cut the vertical line $B\,C$ nearly at the middle point between B and C. Therefore $C\,D$ is nearly one-half the height of the tower, and $C\,A$, the distance which the top is moved from its normal position, would be represented by $C\,D \times \sin C\,D\,A = \frac{1}{2}$ height $\times$ sin of observed change of level. This gives for the length of $C\,A$, on an average clear day, 37.5 feet $\times$ sin $8''.5 = .0185$ inch, or 2. $C\,A = .037$ inch, the major axis of the ellipse.

But for obvious reasons the upper part of the tower would probably be most affected by the heat; hence $C\,D$ should probably be taken somewhat less than one-half the height, and the major axis of the ellipse should be proportionately diminished.

As an indication of the accuracy of the results obtained from such a series of level readings as the above, it may be remarked, that two days, which in the reduction of the tables were noticed as showing unusually large easterly and northerly inclinations, were afterwards found, by reference to the weather record, to have been marked respectively by a north-east storm and a cool north wind. The effect of the cold rain or wind in causing contraction of that side upon which it blew was thus plainly recorded by the level, and a good illustration afforded of the accuracy of which this method of investigation is susceptible.

It remains now to state why the five clear days (July 3–7) were rejected from the discussion. If the readings of Level II. upon those days be examined (see Tables), it will be noticed that, after the first record of July 3d, there is a marked deviation from the means of the Table for Clear Days; the mean readings for these five days being from $8''$ to $13''$ *less* than the corresponding means derived from the rest of the series of Clear Days. So great a variation at once led to a search for any cause which might account for it. And, on consulting the original records, it was found that on the morning of July 3d the workmen, engaged in putting up the tower clock in the room below, had found it necessary to cut a hole through one of the brick arches supporting the floor of the observatory. This necessitated a continual hammering upon the brick wall during a period of several hours; and it was supposed that the consequent jarring of the levels, although not

apparent to the eye, might have caused the one in question — which, it will be remembered, was an unmounted bubble — to settle into some slight hollow of the stone on which it rested, or in some way to alter the zero-point of its scale to the amount indicated above. And as the series (five days) was too short to ascertain with any certainty the amount of this change, those days were rejected entirely. The readings of Level I. for the same five days show an apparent change in its zero-point also, but not to so noticeable an amount.

In regard to the practical bearing of this discussion upon the availability of such towers for mounting astronomical instruments, it may be sufficient, without entering into details, to state the conclusion arrived at in the present case. This was, that the motion of the tower was so great and so uncertain as to make it unfit for the support of a meridian instrument, but not great enough to seriously interfere with the differential measurements for which an equatorial is principally used. The mean hourly change was not more than 1″.2, which, during the few minutes of an observation, would be insignificant unless extreme accuracy was desired, and might be combined with the unknown accidental errors in reducing the observations.

In conclusion, I would express my thanks to Professors Newton and Lyman, of Yale College, to whom I have been indebted for the use of instruments and for valuable suggestions in the conduct of the observations.

Level I.
+ = East.
1 inch = 39″.37.

TOWER MOTION.

CLEAR DAYS = 35 *Days.*

Level II.
+ = North.
1 inch = 51″.7.

Date. 1866.	A.M.	Level I.		Level II.		A.M.	Level I.		Level II.	
	h. m.	Inches.	″	Inches.	″	*h. m.*	Inches.	″	Inches.	″
April 25	8	−0.04	− 1.57	+0.21	+10.86	10.30	+0.28	+11.02	+0.15	+7.76
27	8	−0.06	− 2.36	+0.10	+ 5.17	10.30	+0.125	+ 4.92	+0.09	+4.65
28	8	−0.10	− 3.94	+0.08	+ 4.14	10.30	+0.175	+ 6.89	+0.03	+1.55
30	8	+0.01	+ 0.39	+0.075	+ 3.88	10.30	+0.25	+ 9.84	+0.05	+2.59
May 4	7.40	−0.06	− 2.36	+0.07	+ 3.62	10.30	+0.21	+ 8.27	+0.04	+2.07
5	7.30	−0.27	−10.63	+0.075	+ 3.88	10.45	−0.09	− 3.54	+0.01	+0.52
7	7.30	−0.13	− 5.12	−0.01	− 0.52	10.30	+0.15	+ 5.91	−0.07	−3.62
8	7.45	−0.30	−11.81	+0.06	+ 3.10	10.45	−0.235	− 9.26	+0.01	+0.52
10	7.45	+0.125	− 4.92	+0.115	+ 5.95	10.45	+0.275	+10.83	+0.05	+2.59
11	7.45	−0.22	− 8.66	+0.11	+ 5.69	10.30	+0.055	+ 2.17	+0.05	+2.59
12	7.30	−0.205	− 8.07	+0.125	+ 6.46	10.45	+0.075	+ 2.96	+0.10	+5.17
14	7.30	−0.01	− 0.39	+0.175	+ 9.05	10.30	+0.27	+10.63	+0.175	+9.05
15	7.30	+0.125	+ 4.92	+0.155	+ 8.02	10.50	+0.39	+15.35	+0.13	+6.72
16	7.30	−0.135	− 5.32	+0.125	+ 6.46	10.30	+0.005	+ 0.20	+0.145	+7.50
19	7.30	−0.395	−15.55	+0.11	+ 5.69	10.45	−0.25	− 9.84	+0.11	+5.69
24	7.40	−0.14	− 5.51	+0.08	+ 4.14	10.45	−0.085	− 3.35	+0.08	+4.14
30	7.45	−0.08	− 3.15	+0.105	+ 5.43	10.45	+0.065	+ 2.56	+0.105	+5.43
31	8	−0.21	− 8.27	+0.105	+ 5.43	10.30	−0.03	− 1.18	+0.11	+5.69
June 1						10.40	+0.095	+ 3.74	+0.10	+5.17
6	7.30	−0.34	−13.39	+0.115	+ 5.95	10.45	−0.16	− 6.30	+0.12	+6.20
8	7.30	−0.04	− 1.57	+0.145	+ 7.50	10.45	+0.115	+ 4.53	+0.145	+7.50
9	7.30	+0.015	+ 0.59	+0.14	+ 7.24	10.30	+0.08	+ 3.15	+0.125	+6.46
11	7.30	−0.09	− 3.54	+0.095	+ 4.91	10.50	+0.145	+ 5.71	+0.095	+4.91
12	7.40	−0.135	− 5.32	+0.10	+ 5.17	10.30	+0.16	+ 6.30	+0.075	+3.88
15	8.30	−0.17	− 6.69	+0.095	+ 4.91	10.45	+0.045	+ 1.77	+0.095	+4.91
16						10.45	+0.11	+ 4.33	+0.105	+5.43
19	7.30	−0.06	− 2.36	+0.115	+ 5.95	10.30	+0.205	+ 8.07	+0.095	+4.91
20	8.15	+0.225	+ 8.86	+0.08	+ 4.14	10.50	+0.405	+15.95	+0.085	+4.40
21	7.40	+0.145	+ 5.71	+0.10	+ 5.17	10.30	+0.33	+12.99	+0.055	+2.85
22	8	+0.15	+ 5.91	+0.12	+ 6.20	10.45	+0.29	+11.42	+0.075	+3.88
25	8	−0.015	− 0.59	+0.135	+ 6.98	10.30	+0.185	+ 7.39	+0.125	+6.46
26	7.45	+0.05	+ 1.97	+0.155	+ 8.01					
29	8.30	+0.10	+ 3.94	+0.125	+ 6.46	10.35	+0.25	+ 9.84	+0.11	+5.69
30	8.15	+0.02	+ 0.79	+0.08	+ 4.14					
July 2	7.45	+0.21	+ 8.27	+0.055	+ 2.85					
Means.	7.50		−2″.72		+5″.52	10.38		+4″.79		+4″.48

TOWER MOTION.

CLEAR DAYS = 35 *Days.* — *Continued.*

Level I. + = East. 1 inch = 39″.37.

Level II. + = North. 1 inch = 51″.7.

Date. 1866.	P.M. h. m.	Level I. Inches.	Level I. ″	Level II. Inches.	Level II. ″	P.M. h. m.	Level I. Inches.	Level I. ″	Level II. Inches.	Level II. ″
April 25	12.30	+0.275	+10.83	+0.13	+6.72	3.30	−0.08	− 3.15	+0.06	+ 3.10
27	1	+0.13	+ 5.12	+0.02	+1.03	3.30	−0.25	− 9.84	−0.27	−13.96
28	1	+0.06	+ 2.36	−0.13	−6.72	3.30	−0.19	− 7.48	−0.24	−12.41
30	1	+0.10	+ 3.94	−0.10	−5.17	3.30	−0.11	− 4.33	−0.29	−14.99
May 4	1	+0.08	+ 3.15	−0.03	−1.55	3.30	−0.115	− 4.53	−0.11	− 5.69
5	1	−0.14	− 5.51	−0.04	−2.07	3.30	−0.19	− 7.48	−0.14	− 7.24
7	1	+0.225	+ 8.86	−0.18	−9.31	3.30	−0.25	− 9.84	−0.34	−17.58
8	1	−0.22	− 8.66	−0.15	−7.76	3.30	−0.46	−18.11	−0.325	−16.80
10	1	+0.22	+ 8.66	−0.09	−4.65	3.30	+0.005	+ 0.20	−0.255	−13.19
11	1	+0.02	+ 0.79	−0.10	−5.17	3.30	−0.24	− 9.45	−0.18	− 9.31
12	1	+0.08	+ 3.15	−0.035	−1.81	3.30	−0.12	− 4.72	−0.18	− 9.31
14	1	+0.21	+ 8.27	+0.17	+8.79	3.30	0.00	0.00	+0.075	+ 3.88
15						3.30	−0.07	− 2.76	+0.07	+ 3.62
16						3.45	−0.345	−13.59	+0.07	+ 3.62
19	1	−0.245	− 9.65	+0.115	+5.95	2.45	−0.37	−14.57	+0.08	+ 4.14
24	1	−0.065	− 2.56	+0.08	+4.14	3.30	−0.20	− 7.87	+0.08	+ 4.14
30	1	+0.035	+ 1.38	+0.11	+5.69	3.30	−0.18	− 7.19	+0.10	+ 5.17
31	1	−0.03	− 1.18	+0.115	+5.95	3.30	−0.28	−11.02	+0.08	+ 4.14
June 1	1	+0.04	+ 1.57	+0.105	+5.43	3.30	−0.18	− 7.19	+0.045	+ 2.33
6	1	−0.19	− 7.48	+0.06	+3.10					
8	1	+0.07	+ 2.76	+0.12	+6.20	3.30	+0.015	+ 0.59	+0.09	+ 4.65
9	1	−0.015	− 0.59	+0.115	+5.95	3.30	−0.07	− 2.76	+0.115	+ 5.95
11	1	+0.14	+ 5.51	+0.07	+3.62	3.30	−0.145	− 5.71	−0.06	− 3.10
12	1	+0.12	+ 4.72	+0.035	+1.81	3.45	−0.205	− 8.07	−0.10	− 5.17
15	1	+0.02	+ 0.79	+0.08	+4.14	3.30	−0.23	− 9.06	−0.02	− 1.03
16	1	+0.095	+ 3.74	+0.035	+1.81	3.40	−0.33	−12.99	−0.11	− 5.69
19	1	+0.165	+ 6.50	+0.09	+4.65	3.30	+0.025	+ 0.99	+0.07	+ 3.62
20	1	+0.325	+12.80	+0.015	+0.78	3.30	−0.03	− 1.18	−0.08	− 4.14
21	1	+0.26	+10.24	−0.01	−0.52	3.45	−0.07	− 2.76	−0.135	− 6.98
22	1	+0.21	+ 8.27	+0.00	0.00	3.50	−0.145	− 5.71	−0.10	− 5.17
25	1	+0.135	+ 5.32	+0.02	+1.03					
26										
29	1	+0.19	+ 7.48	+0.11	+5.69	3.30	+0.08	+ 3.15	+0.105	+ 5.43
30	1	+0.17	+ 6.69	−0.005	−0.26	4	−0.09	− 3.54	−0.125	− 6.46
July 2	1	+0.39	+15.35	−0.055	−2.85	3.45	−0.02	− 0.79	−0.18	− 9.31
Means.	12.59		+3″.52		+1″.08	3.32		−5″.96		−3″.55

Level I.
+ = East.
1 inch = 39″.37.

TOWER MOTION.

CLEAR DAYS = 35 *Days.* — *Concluded.*

Level II.
+ = North.
1 inch = 51″.7.

Date. 1866.	P.M. h. m.	LEVEL I.		LEVEL II.		P.M. h. m.	LEVEL I.		LEVEL II.	
		Inches.	″	Inches.	″		Inches.	″	Inches.	″
April 25	6	−0.13	− 5.12	+0.10	+ 5.17					
27	6	−0.44	−17.32	−0.26	−13.44	10.30	−0.295	−11.62	−0.07	−3.62
28	6	−0.25	− 9.84	−0.18	− 9.31	10.30	−0.20	− 7.87	−0.04	−2.07
30	6	−0.28	−11.02	−0.30	−15.51					
May 4	6	−0.26	−10.24	−0.215	−11.12	10.30	−0.20	− 7.87	−0.03	−1.55
5	6	−0.43	−16.93	−0.28	−14.48	10.40	−0.335	−13.19	−0.09	−4.65
7	6	−0.34	−13.39	−0.36	−18.61	10.15	−0.34	−13.39	−0.085	−4.40
8	6	−0.36	−14.17	−0.23	−11.89	10.30	−0.28	−11.02	−0.09	−4.65
10	6	−0.20	− 7.87	−0.24	−12.44					
11	6	−0.25	− 9.84	−0.10	− 5.17	10.40	−0.22	− 8.66	+0.06	+3.10
12	6	−0.305	−12.01	−0.20	−10.34	10	−0.225	− 8.86	+0.00	0.00
14						12	−0.10	− 3.94	+0.155	+8.02
15	6	−0.20	− 7.87	+0.08	+ 4.14	11.20	−0.17	− 6.69	+0.125	+6.46
16	6	−0.325	−12.80	+0.09	+ 4.65					
19	6	−0.525	−20.67	+0.06	+ 3.10	10.30	−0.45	−17.72	+0.115	+5.95
24	6	−0.29	−11.42	+0.08	+ 4.14					
30	6	−0.265	−10.44	+0.10	+ 5.17	10.30	−0.225	− 8.86	+0.11	+5.69
31	6	−0.37	−14.57	+0.06	+ 3.10					
June 1	6	−0.355	−13.98	+0.045	+ 2.33	10.40	−0.28	−11.02	+0.09	+4.65
6										
8	6	−0.08	− 3.15	+0.12	+ 6.20	10.45	−0.11	− 4.33	+0.145	+7.50
9	5.30	−0.31	−12.40	+0.11	+ 5.69					
11	6	−0.38	−14.96	−0.09	− 4.65					
12	6	−0.28	−11.02	−0.105	− 5.43	10.30	−0.22	− 8.66	+0.045	+2.33
15	6	−0.395	−15.55	−0.05	− 2.59					
16	6	−0.49	−19.29	−0.11	− 5.69	10.50	−0.33	−12.99	+0.05	+2.59
19	6	−0.08	− 3.15	+0.07	+ 3.62					
20	6	−0.15	− 5.91	−0.09	− 4.65	10.30	−0.05	− 1.97	+0.04	+2.07
21	6	−0.145	− 5.71	−0.115	− 5.95					
22	6	−0.205	− 8.07	−0.065	− 3.36					
25										
26	6	+0.03	+ 1.18	−0.155	− 8.01					
29	6	−0.01	− 0.39	+0.06	+ 3.10					
30	5.30	−0.005	− 0.20	−0.08	− 4.14					
July 2	6	−0.19	− 7.48	−0.185	− 9.57					
Means.	5.58		−10″.17		−3″.93	10.39		−9″.33		+1″.61

TOWER MOTION.

Level I. + = East. 1 inch = 89″.37.

Level II. + = North. 1 inch = 51″.7.

Cloudy Days = 24 *Days.*

Date. 1866.	A.M. h. m.	Level I. Inches.	Level I. //	Level II. Inches.	Level II. //	A.M. h. m.	Level I. Inches.	Level I. //	Level II. Inches.	Level II. //
April 24	8	—0.455	—17.92	+0.23	+11.89	10.30	—0.36	—14.17	+0.215	+11.12
26	7.15	—0.10	— 3.94	+0.13	+ 6.72	10	—0.14	— 5.51	+0.13	+ 6.72
May 1	8	—0.20	— 7.87	+0.075	+ 3.88	10.30	—0.15	— 5.91	+0.06	+ 3.10
2	8	—0.50	—19.69	+0.10	+ 5.17	10.30	—0.50	—19.69	+0.10	+ 5.17
3	8	—0.34	—13.39	+0.08	+ 4.14	10.30	—0.11	— 4.33	+0.065	+ 3.36
9	7.30	—0.30	—11.81	+0.05	+ 2.59	10.30	—0.305	—12.01	+0.045	+ 2.33
17	8	—0.33	—12.99	+0.14	+ 7.24	10.45	—0.34	—13.39	+0.135	+ 6.98
18	7.30	—0.34	—13.39	+0.12	+ 6.20	10.45	—0.355	—13.98	+0.12	+ 6.20
21	7.30	—0.34	—13.39	+0.13	+ 6.72	10.45	—0.32	—12.60	+0.11	+ 5.69
22	7.30	—0.28	—11.02	+0.115	+ 5.95	10.45	—0.19	— 7.48	+0.115	+ 5.95
23	7.30	—0.135	— 5.32	+0.08	+ 4.14	10.40	—0.06	— 2.36	+0.095	+ 4.91
25	9.20	—0.23	— 9.06	+0.08	+ 4.14	10.45	—0.16	— 6.30	+0.08	+ 4.14
26	7.40	—0.20	— 7.87	+0.09	+ 4.65	10.45	—0.095	— 3.74	+0.115	+ 5.95
28	7.30	—0.275	—10.83	+0.12	+ 6.20	10.45	—0.30	—11.81	+0.125	+ 6.46
29	7.30	—0.21	— 8.27	+0.11	+ 5.69	10.45	—0.08	— 3.15	+0.11	+ 5.69
June 2	7.30	—0.27	—10.63	+0.09	+ 4.65	10.30	—0.265	—10.44	+0.09	+ 4.65
4	7.30	—0.28	—11.02	+0.11	+ 5.69	10.50	—0.29	—11.42	+0.11	+ 5.69
5	7.30	—0.32	—12.60	+0.115	+ 5.95	10.30	—0.32	—12.60	+0.11	+ 5.69
7	7.35	—0.155	— 6.11	+0.125	+ 6.46	10.40	—0.055	— 2.17	+0.14	+ 7.24
13	8.30	—0.19	— 7.48	+0.115	+ 5.95	11	—0.22	— 8.66	+0.11	+ 5.69
14	7.30	—0.275	—10.83	+0.095	+ 4.91	11	—0.275	—10.83	+0.095	+ 4.91
18	8	—0.14	— 5.51	+0.13	+ 6.72	10.45	—0.165	— 6.50	+0.13	+ 6.72
23	7.30	—0.09	— 3.54	+0.11	+ 5.69	10.30	—0.09	— 3.54	+0.11	+ 5.69
28	8.30	—0.105	— 4.14	+0.16	+ 8.27	10.45	—0.095	— 3.74	+0.16	+ 8.27
Means.	7.47		—9″.94		+5″.82	10.39		—8″.60		+5″.76

All Days = 59 *Days.*

Means.			—5″.76		+5″.64			—0″.95		+5″.03

Rejected as Unreliable = 5 *Clear Days.*

July 3	7.35	+0.125	+ 4.92	+0.04	+ 2.67	10.40	+0.175	+ 6.89	—0.11	— 5.69
4	7.40	+0.08	+ 3.15	—0.07	— 3.62	10.45	+0.32	+12.60	—0.13	— 6.72
5	7.35	—0.07	— 2.76	—0.01	— 0.52	10.30	+0.13	+ 5.12	—0.065	— 3.36
6	7.50	—0.005	— 0.20	—0.06	— 3.10	10.45	+0.205	+ 8.07	—0.14	— 7.24
7	7.40	+0.005	+ 0.20	—0.085	— 4.40	10.30	+0.285	+11.22	—0.155	— 8.02
Means.			+1″.06		—1″.91			+8″.78		—6″.21

TOWER MOTION.

Level I. + = East. 1 inch = 39″.37.

Level II. + = North. 1 inch = 51″.7.

Cloudy Days = 24 *Days.* — *Continued.*

Date. 1866.	P.M. h. m.	Level I. Inches.	Level I. ″	Level II. Inches.	Level II. ″	P.M. h. m.	Level I. Inches.	Level I. ″	Level II. Inches.	Level II. ″
April 24	1	−0.36	−14.17	+0.21	+10.86	4	−0.315	−12.40	+0.195	+10.08
26	12.30	−0.16	− 6.30	+0.12	+ 6.20	3	−0.16	− 6.30	+0.12	+ 6.20
May 1	1	−0.18	− 7.19	+0.05	+ 2.59	3.30	−0.18	− 7.19	+0.07	+ 3.62
2	1	−0.44	−17.32	+0.09	+ 4.65	3.30	−0.45	−17.72	−0.11	− 5.69
3	1	−0.17	− 6.69	+0.005	+ 0.26	3.30	−0.175	− 6.89	+0.01	+ 0.52
9						2.30	−0.325	−12.80	−0.03	− 1.55
17	1	−0.325	−12.80	+0.13	+ 6.72	3.30	−0.315	−12.40	+0.125	+ 6.46
18	1	−0.375	−14.77	+0.125	+ 6.46	4	−0.37	−14.57	+0.115	+ 5.95
21	1	−0.29	−11.42	+0.145	+ 7.50	4	−0.38	−14.96	+0.145	+ 7.50
22	1	−0.18	− 7.19	+0.105	+ 5.43	3.30	−0.275	−10.83	+0.105	+ 5.43
23	1	−0.06	− 2.36	+0.085	+ 4.40	3.30	−0.10	− 3.94	+0.085	+ 4.40
25	1	−0.15	− 5.91	+0.09	+ 4.65	3.30	−0.15	− 5.91	+0.07	+ 3.62
26	1	−0.08	− 3.15	+0.10	+ 5.17	3.30	−0.225	− 8.86	+0.05	+ 2.59
28	1	−0.285	−11.22	+0.135	+ 6.98	4	−0.31	−12.20	+0.125	+ 6.46
29	1	−0.155	− 6.11	+0.11	+ 5.69	3.30	−0.155	− 6.11	+0.11	+ 5.69
June 2	1	−0.25	− 9.84	+0.09	+ 4.65	3.40	−0.345	−13.59	+0.07	+ 3.62
4	1	−0.31	−12.20	+0.11	+ 5.69	3.30	−0.31	−12.20	+0.11	+ 5.69
5	1	−0.335	−13.19	+0.115	+ 5.95	3.30	−0.335	−13.19	+0.11	+ 5.69
7	1	−0.035	− 1.38	+0.115	+ 5.95	3.30	−0.215	− 8.47	+0.065	+ 3.36
13	1	−0.235	− 9.26	+0.11	+ 5.69					
14	1	−0.285	−11.22	+0.09	+ 4.65					
18	1	−0.205	− 8.07	+0.125	+ 6.46	3.30	−0.23	− 9.06	+0.125	+ 6.46
23	1	−0.09	− 3.54	+0.07	+ 3.62					
28	1	−0.095	− 3.74	+0.16	+ 8.27	4	−0.09	− 3.54	+0.16	+ 8.27
Means.	12.59		−8″.65		+5″.59	3.33		−10″.15		+4″.49

All Days = 59 *Days.*

Means.			−1″.57		+2″.97			−7″.62		−0″.37

Rejected as Unreliable = 5 *Clear Days.*

July 3	1	+0.24	+ 9.45	−0.28	−14.48	3.40	−0.07	− 2.76	−0.38	−19.65
4	1	+0.15	+ 5.91	−0.20	−10.34	3.30	+0.01	+ 0.39	−0.22	−11.37
5	1	−0.155	− 6.11	−0.17	− 8.79	3.45	−0.16	− 6.30	−0.33	−17.06
6	1	−0.12	− 4.72	−0.24	−12.41	3.45	−0.065	− 2.56	−0.36	−18.61
7	1.10	+0.22	+ 8.66	−0.30	−15.51	3.30	−0.14	− 5.51	−0.43	−22.23
Means.			+2″.64		−12″.31			−3″.35		−17″.28

Level I.
+ = East.
1 inch = 89″.87.

TOWER MOTION.

Cloudy Days = 24 *Days.* — *Concluded.*

Level II.
+ = North.
1 inch = 51″.7.

Date. 1866.	P.M. h. m.	Level I. Inches.	Level I. ″	Level II. Inches.	Level II. ″	P.M. h. m.	Level I. Inches.	Level I. ″	Level II. Inches.	Level II. ″
April 24	6	—0.29	—11.42	+0.195	+10.08	12	—0.20	— 7.87	+0.195	+10.08
26	6	—0.14	— 5.51	+0.10	+ 5.17	11.15	—0.245	— 9.65	+0.215	+11.12
May 1	6	—0.225	— 8.86	+0.07	+ 3.62					
2	6	—0.47	—18.50	—0.075	— 3.88	10.40	—0.485	—19.10	+0.07	+ 3.62
3	6	—0.25	— 9.84	+0.04	+ 2.07	10.30	—0.25	— 9.84	+0.07	+ 3.62
9	6	—0.37	—14.57	—0.04	— 2.07	10.40	—0.34	—13.39	+0.025	+ 1.29
17										
18	6	—0.37	—14.57	+0.12	+ 6.20					
21	6	—0.42	—16.54	+0.145	+ 7.50	10.40	—0.305	—12.01	+0.13	+ 6.72
22	6	—0.27	—10.63	+0.095	+ 4.91					
23	6	—0.125	— 4.92	+0.08	+ 4.14					
25	6	—0.175	— 6.89	+0.075	+ 3.88	11	—0.195	— 7.68	+0.09	+ 4.65
26	6	—0.24	— 9.45	+0.045	+ 2.33	10.30	—0.245	— 9.65	+0.08	+ 4.14
28	6	—0.33	—12.99	+0.13	+ 6.72	10.30	—0.30	—11.81	+0.12	+ 6.20
29	6	—0.155	— 6.11	+0.11	+ 5.69					
June 2	6	—0.44	—17.32	+0.05	+ 2.59	10.30	—0.34	—13.39	+0.08	+ 4.14
4	6	—0.32	—12.60	+0.11	+ 5.69	10.30	—0.32	—12.00	+0.115	+ 5.95
5	6	—0.355	—13.98	+0.11	+ 5.69	10.40	—0.36	—14.17	+0.115	+ 5.95
7	6	—0.26	—10.24	+0.07	+ 3.62					
13										
14	6.30	—0.30	—11.81	+0.095	+ 4.91					
18	6	—0.475	—18.70	+0.095	+ 4.91	10.40	—0.37	—14.57	+0.115	+ 5.95
23	6.30	—0.115	— 4.53	—0.03	— 1.55					
28										
Means.	6.3		—11″.43		+3″.91	10.47		—11″.98		+5″.65

All Days = 59 *Days.*

Means.			—10″.67		—0″.78			—10″.48		+3″.86

Rejected as Unreliable = 5 *Clear Days.*

July 3	6	—0.11	— 4.33	—0.41	—21.20					
4										
5	6	—0.32	—12.60	—0.33	—17.06					
6	6.10	—0.13	— 5.12	—0.36	—18.61					
7	6	—0.25	— 9.84	—0.41	—21.20					
Means.			—[illegible]		—15″.61					

5. Evaporating Niches, at the Laboratory of the Maine State College of Agriculture and the Mechanic Arts.

By S. F. Peckham, of Orono, Maine.

Few questions are more perplexing to those intrusted with the construction of Laboratories than those arising in reference to ventilation. The various devices that have been resorted to, in order to adapt buildings originally constructed for other purposes to laboratory uses, need not be mentioned here, as all chemists are more or less familiar with them. Many of them are valuable and efficient to a certain extent, but every one who has been forced to resort to their use has never been satisfied with their operation. Even in the construction of new buildings, the exercise of economy in reference to room has frequently led to the necessity of devoting a building to many other, as well as to laboratory uses. The basements of large buildings,— like those of the Massachusetts Institute of Technology, and Sheffield Scientific School,— perhaps because less readily adapted to the uses of other departments, have been devoted to laboratories, where low ceilings and windows have been scarcely compensated by the increased height of the flues. The laboratories of these institutions, however, have methods of ventilation much superior to those of earlier construction.

The building for laboratory uses just completed at the Maine College of Agriculture and the Mechanic Arts, at Orono, contains special provisions for securing thorough ventilation, superior to any that we have met. The style, size, and general arrangement of the building are almost identical with those of Brown University, Providence, R.I., having been built after plans furnished by the same architect. The main building, which is of two stories, thirteen feet six inches and fourteen feet in height respectively, contains twenty flues, twelve of which are in two stacks of six each, and the other eight in four stacks of two each. These contain numerous registers in both stories, and furnish ample ventilation; especially as the rooms, with the exception of the private laboratory of the Professor, are none of them used for purposes of analysis or research, but as Library and Weighing Room, Cabinet, Lecture Room, and Apparatus Rooms.

An L, fifty feet by thirty-eight, and of only one story, contains the working-room for students. It is of the entire size of the L, and

fifteen feet high, lighted from the sides by ten windows, each eight feet in height. The light is very ample, and the unusual height of the room lessens very much the necessity for extraordinary measures for ventilation. Means to this end, however, have not been neglected; and while they are more preventive than otherwise, with ordinary precautions, together with the unusual roominess of the apartment, the results attained have been in the highest degree satisfactory.

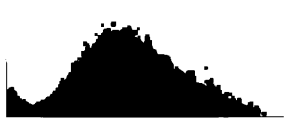
A few years after the building at Brown University was completed, the new laboratories at the Prussian Universities of Berlin and Bonn were built. The method adopted in these laboratories, to secure freedom from products which it is usually found necessary to remove by ventilation, are novel and effectual, and were very fully described in the London "Chemical News"* during the autumn of 1866. Niches were constructed within the walls of the building, connected with the outer air by flues, and so arranged as to be completely shut off from the room by a sliding sash.

When I came to Orono, the main building alone was erected, with the L which contains the student's laboratory yet to be constructed. I determined to make the ventilation of the L more satisfactory than that of Brown, if I could devise any plan that could be brought within the means at the disposal of the Board of Trustees. I estimated that to build the niches like those at Berlin, if soapstone were substituted for sandstone, would add to the cost of the building from one hundred and fifty to two hundred dollars each, or in the aggregate from twelve hundred to sixteen hundred dollars. This estimate made them too expensive, and I sought in every way to reduce the cost to a minimum amount.

While the Prussian niches were lined with slabs of sandstone at the top, bottom, and sides, I concluded that only the slab that formed the base must necessarily be constructed of similar material. Some ordinary plaster walls, on the inside of a common hood, at Brown University, had stood for several years in constant use, when protected by a paint composed largely of paraffine.† I therefore determined to make the roof and sides of the niches of brickwork, and protect the heavy coating of plaster, first with a

* Chemical News, vol. xiv., p. 181, et seq.

† This paint was first used, I believe, by Professor John Pierce. That used here was prepared by dissolving enough paraffine in naphtha to leave a thin coating by evaporation, then sufficient zinc white, ground in oil, was added to give a proper body.



very smooth hard finish of plaster of Paris, and then with a heavy coat of paraffine paint. These surfaces are very smooth and hard, and do not appear to be affected by chemicals, although of course they have not yet stood the test of time. The base is made of a single slab of soapstone. Its form, as well as that of the niche, together with the position of the slab when set, is shown in the following sections, which are drawn to a scale of one twenty-fourth.

Fig. 1 represents the upper surface of the slab, with the smaller slab in place.

Fig. 2 represents a section of the slab through the line *f g*, Fig. 1.

Fig. 3 represents a section of the slab through the line *d e*, Fig. 1.

Fig. 4 represents the slab with smaller slab removed.

Fig. 5 represents the under-surface of the slab.

Fig. 6 represents a vertical section of the niche, along the line *f g* of the slab when set.

Figures 1 to 5 represent a slab of soapstone twenty-seven (27) inches square, by four (4) inches in thickness. At *a* and *a*, Fig. 1, are slots, one by three inches, that pass through the slab, and upon the opposite side terminate the horse-shoe-shaped groove, Fig. 5. At *c*, Fig. 1, is a smaller movable slab twelve by thirteen inches, and one inch thick, which is shown in section at Figs. 2 and 3. This small slab contains nine three-quarter inch perforations, connected on the upper surface by grooves. At *b*, Figures 1, 2, and 4, is a three-inch circular depression, to receive the lower end of the conical earthenware pipe, *r b*, Fig. 6.

Fig. 2 shows the two slabs in section along the line *f g*, Fig. 1. The cavity beneath the smaller slab, *c*, is shown with the perforation, *h*, Figures 4 and 5, which passes through the slab and receives the lead pipe, *o*, Fig. 6.

Fig. 3 shows the two slabs in section along the line *d e*, Fig. 1. The slot, *a*, is shown passing through the slab and communicating with the groove at *u*.

Fig. 4 shows the large slab with the smaller slab removed, and also the cavity which appears in section beneath *c*, Fig. 2. The slab, *c*, rests squarely on a ledge three-quarters of an inch wide all around, from which the sides slope to the centre.

Fig. 5 shows the under-surface of the slab with the horse-shoe-shaped groove, which is three inches wide, and half-an-inch deep in the centre.

The dotted lines at Fig. 1 show the outline of the brick wall forming the sides of the niche.

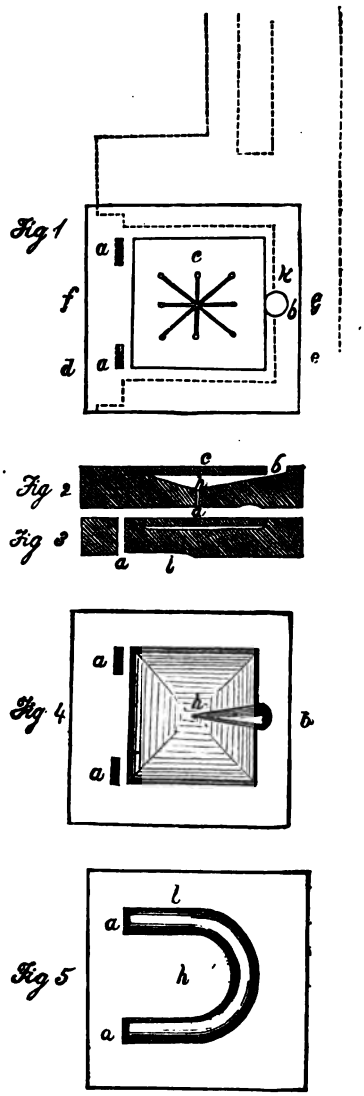


Fig. 6.

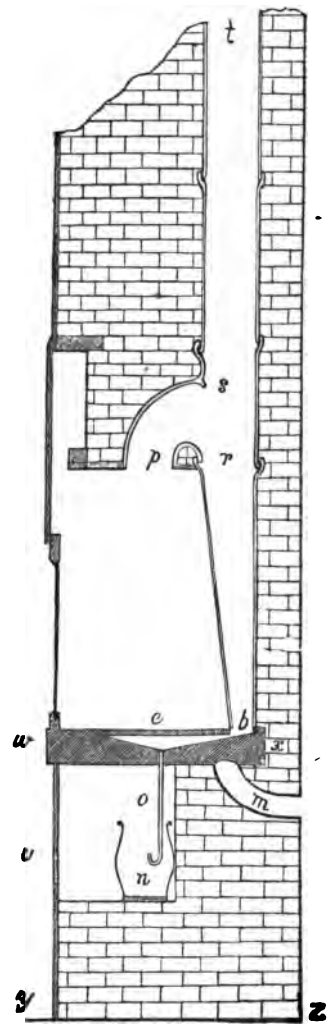


Fig. 6 shows a vertical section of the niche along the line *f g*, Fig. 1; *y z* is the level of the finished floor; *n* is the door and

panel-work covering the brickwork, and open space beneath the slab which contains the earthen jar, *n*, to receive the drip from the pipe, *o*; *m* is a cast-iron pipe, three inches in diameter, which connects the posterior portion of the groove, Fig. 5, with the outer air. The slab, *w x*, is set one course of brick from the outside of the building: *r b* is a conical earthenware pipe, thirty-three inches in length, glazed inside and out, of three inches *external* diameter at the lower end, and six inches *internal* diameter at the upper end. With this pipe is connected at the upper extremity what is called a Y-joint, having three six-inch openings, *p*, *r*, and *s*. At *s* a projection is thrown into the pipe, from which any products of condensation flowing down the flue will drop through the orifice, *r*, instead of *p*. The flue is then carried out of the roof of the building by a common six-inch glazed drain-pipe, in two feet lengths.

When the niche is closed, a constant circulation of fresh air is kept up through the pipe, *m*, Fig. 6, the groove, Fig. 5, the slots, *a* and *a*, Figures 1, 4, and 5, the branch, *p s*, and flue, *s t*, Fig. 6. The niches are each supplied with gas, and when the draft is inadequate a Bunsen's burner placed at *p* increases it sufficiently. Any products of condensation will flow down the flue, and passing down *r b*, beneath the slab, *c*, are finally discharged into the jar, *n*, through the drip, *o*. Any slops within the niche flow through the orifices in *c* to the same receptacle. The panel-work above and below the slab, with the mouldings that hold the sliding sash, may be finished to correspond with the other woodwork of the room.

A comparison of these sections with the illustrations in the xiv. volume of the "Chemical News," accompanying the article above referred to, will show that the niches here and in Prussia are essentially unlike only in the material of which they are constructed. They are identical in every respect necessarily involved in their operation; and while, at rare intervals of excessively low barometer, the unaided draught of the flues is insufficient, it is usually so strong as to interfere with the combustion of lamps, and removes without difficulty every trace of sulphydric acid set free within the niche. Even at the intervals referred to above, the defective draught may be remedied by burning a lamp within the niche, and thus ensuring its perfect action.

We consider the introduction of these niches in every respect a success, and heartily recommend the plan to all who may be seek-

ing to avoid the necessity of performing evaporations in the open laboratory, as in many respects preferable to any that has come under our notice.

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6. The Chemical Equivalent of Ether. By H. F. Walling, of Boston, Mass.

Supposing the ether of space to be a gas, and therefore that it has an atomic weight or chemical equivalent, I have thought that, under the dynamic theory of gaseous elasticity, this atomic weight could be computed in a simple manner whenever certain data should be sufficiently well determined, and that even now a tolerable approximation may be attained.

In the equation

$$w\, v^2 = c\, t,$$

let w represent the weight of an atom or molecule of any gas, v the velocity of an acoustic wave in this gas, and t any temperature reckoned from absolute zero in degrees which represent equal accessions of energy to the gaseous atoms or molecules. Then will c be constant, or very nearly so, for all gases at temperatures considerably above that of liquefaction.

To prove this, we may first show that v^2 changes in a constant ratio with t in any gas, w remaining constant.

Now the velocity of an acoustic wave is ascertained by calculating the velocity acquired by a body in falling a distance equal to one half the length of that homogeneous column of the gas, which has a sufficient weight, when vertically placed, to produce by its own gravity a pressure equal to that maintained in the gas. The velocity thus found is multiplied by a coefficient, constant for all perfect gases and at all temperatures.* Since the height of the

* This coefficient, as found by experiment, is $\sqrt{1.42}$, and it represents the amount of acceleration which is produced by the disturbance of temperature developed in the condensation and rarefaction of the wave.

The cause and amount of this acceleration was first indicated by La Place, $\frac{1.42}{1.00}$, the square of the above coefficient, being the ratio of the amount of heat expended, including the *external work* done, when a gas is heated and allowed to

balancing column is, according to the law of Gay Lussac, proportional to the absolute temperature, and since the square of the velocity acquired in falling is in proportion to the height of the fall, v^2 maintains a constant ratio to t, and c is therefore constant so long as w remains unchanged.

Moreover, since the densities of different gases at a common temperature and pressure are proportional to their atomic weights, the heights of their balancing columns, and therefore v^2 must be *inversely* proportional to w. Hence the product $w\,v^2$ is the same for all gases having the same temperature, and hence c is constant for all gases at all temperatures considerably above liquefaction.

Assuming, for hydrogen, that $w = 1$, and taking the velocity of sound in that gas at zero Centigrade to be 4164 feet per second, as determined by Dulong, we have $(4164)^2\,w = 273\,c$; zero Centigrade being equal to 273 degrees of *absolute* temperature. Whence $c = 63512$.

A wave of light is generally supposed to be similar in kind to a wave of sound. If this be true, we have

$$w\,v^2 = 63512\,t$$

when applied to ether. The velocity of light is, in round numbers, 1,000,000,000 feet per second, hence

$$(1000000000)^2\,w = 63512\,t,$$

in which t represents the absolute temperature of the interplanetary spaces. Hopkins estimates this at — 38°.5 cent. = 234°.5 ab. temp.; Fourier at — 50° = 223° ab. temp.; and Pouillet at — 142° = 131° ab. temp.*

The values of w, calculated for ether with these values of t, are as follows: —

$$t = 234°.5,\ w = .000000000014893564$$
$$t = 223°,\ w = .000000000014163176$$
$$t = 131°,\ w = .000000000008320072$$

Taking the mean of the estimated temperatures, $t = 196°$, $w = .000000000012448352$.

Comparing these values with the fraction $\frac{1}{2^{36}} = \frac{1}{68719476736}$

expand under a constant pressure, to the amount expended to produce an equal elevation of temperature when no external work is performed, the *volume* remaining constant. It is now believed that this ratio is the same for all gases whose powers of absorption and radiation are inconsiderable.

* Nichols, Cyc. of Phys. Science, art. Temperature.

= .000000000014551912, it appears that the atomic weight of ether is probably equal to what that of hydrogen would be, after it had undergone not less than thirty-six, nor more than thirty-seven successive halvings.

Perhaps the objection will be raised to this conclusion, that the transverse vibrations which constitute light indicate that their medium is solid rather than fluid, and therefore that the relation between its atomic weight and wave velocity is different from that of ordinary gases.

I have, on previous occasions, advanced the supposition that the atoms of bodies, in consequence of their momentum and mutual attractions, fall into a linear arrangement, in which contiguous atoms approximate very closely; that the "elemental fibres" thus constituted intersect each other so as to occupy space in its three dimensions, forming the edges of imaginary cubes in gases; that the atoms, being *non-impenetrable*, traverse freely each line of fibre in both of its directions, tending, by mutual attractions and the accelerations produced by temporary *huddlings*, to maintain an equidistance of atoms in their linear arrangement; and that longitudinal vibrations, *i.e.*, along the fibres (condensations and rarefactions), in consequence of the mutual actions and reactions of intersecting fibres, are accompanied by transverse vibrations (undulations like those of stretched cords), which in ether constitute light, — the *resultant* impulses which produce dynamic effects upon interposed bodies being radial for the longitudinal, and concentric for the transverse vibrations.

This hypothesis, if tenable, of course removes objections to the above conclusion, founded upon a supposed constitutional dissimilarity between ether and ordinary gases.

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7. Phosphates of Soda and Potash. By J. Lawrence Smith, of Louisville, Ky.

This is certainly one of the novelties of the Paris Exhibition in the chemical department, and their production starts with the nodules of phosphate of lime, that have been recently found very widely disseminated in almost every country. The process was

discovered and perfected by Boblique. The nodules are more or less impure. Those from Ardennes contain:

Silica	35 per cent.
Lime	28 „ „
Phosphoric acid	19 „ „
Phosphorus	8 „ „

(The analysis is given as I find it, although I do not understand exactly how the 8 per cent. phosphorus is combined.)*

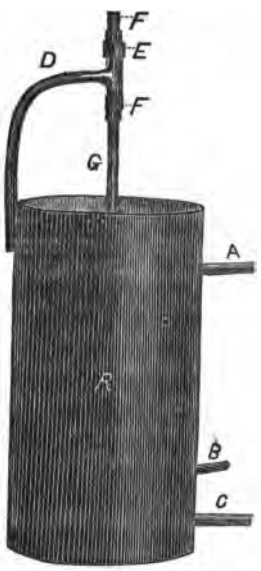
To 100 lbs. of crushed nodules (no necessity of pulverizing) 60 of iron ore is added. The mixture is melted in a blast-furnace of the form of a cupola; and the result is a phosphuret of iron, containing 20 per cent. of phosphorus and a slag of silicates.

To form the phosphate of soda, 100 parts of the pulverized phosphuret is melted, in the ordinary furnace for manufacturing soda, with 200 parts of dry sulphate of soda, and 30 parts of fine charcoal. The mixture is stirred after it is fused; and, when the reaction is completed and the mass is perfectly fluid, it is run into blocks of 1,200 or 1,500 lbs. Exposed to the air for several days, the blocks crumble to powder, and the mass is then submitted to a leaching operation; and the washings, on being concentrated, furnish crystals of tribasic phosphate of soda PO_6 3NaO. The residue is a sulphuret of iron and sodium, which is not thrown away, but roasted in the pyritic furnace of the manufacturer of sulphuric acid, and made to furnish sulphuric acid: and the residue now consists of oxide of iron and sulphate of soda. The sulphate of soda is washed out; and the oxide of iron may be used to operate again on the nodules of phosphate of lime, and the same sulphate of soda also used a second time. Thus the same sulphur and the same iron perform their function over and over again, furnishing an example of one of the most perfect manufacturing processes known. By using sulphate of potash, the potash salt is formed with equal facility.

* Probably the analyst intended to say that the 19 phosphoric acid contained 8 phosphorus.

8. A REGULATOR TO MAINTAIN A CONSTANT LEVEL IN THE WATER-BATHS OF A LABORATORY. By J. LAWRENCE SMITH, of Louisville, Ky.

ALL chemists, who work much or little in the laboratory, realize the importance of having a constant supply of water for the water-baths, and various devices have been resorted to for the purpose of accomplishing this end. One method is to have reservoirs of large capacities attached to the water-baths, which would hold several litres of water. Still more recently, Professor Bunsen devised a method which was a decided improvement on the above, and which has been fully described in the various chemical journals. The principal objection to it will be mentioned further on. Conceiving that a plan I have been employing for some time in my laboratory is superior to and simpler than that of Professor Bunsen, and as this last has excited the attention of practical chemists, it may be as well to describe it for the benefit of those who may choose to employ it.



It consists, in the first place, of a cylindrical vessel, *R*, made of tin, zinc, copper, or wood, of from two to three litres capacity (copper is to be preferred from its convenience and durability). It has soldered on its side, at convenient places and distances, three short pieces of brass tube about 1 centimetre diameter, and 5 centimetres long. The lower one, *C*, is used to draw off the water from the vessel; the second one, *B*, connects with a tube around the laboratory, which can be connected, by lateral pipes, with the water-baths; the third is for overflow. On the rim, and arched over, is soldered a brass rod or tube, *D*, about 8 millimetres in diameter, having a short piece of brass tube, *E*, 1 centimetre in diameter and 5 centimetres long, soldered at right angles to the end of the tube, through which a glass tube, *G*, slides easily, and is pressed and bound by two short pieces of gum-tube, *F F*, 2 or 3

centimetres long, slipped upon the upper and lower end of the short tube.

The second piece, constituting the instrument, is a hollow ball, *H*, of thin brass (two of the thin oval cups spun by the lamp-makers serve remarkably well for its construction; all that is necessary being to solder the two together, first slipping one a little distance into the other), and through the centre is passed a brass tube, *I I*, of about 1 centimetre diameter, projecting 3 or 4 centimetres from the ends of the ball. This tube is soldered into the ends of the ball, so as to make the cavity of it air-tight. On one of the projecting ends, at *K*, the tube is cut one-half the way through with a V-shaped cut. In this end of the tube a plug of brass or wood is introduced, having on its end a soft, smooth cap of india-rubber, made by tying one or two thicknesses of thin gum over the end. This is introduced as far as the lower part of the V-shaped cut, and fastened in the tube in any convenient way. There is only one other piece that is necessary; viz., a glass tube, *G*, that passes easily through the tubes in the cup and in the float. This glass tube is drawn down carefully, so as not to make the sides too thin; it is broken *square* across, and the end rubbed a little with a fine file and water, so that it may set squarely on the gum-pad at the bottom of the tube. The diameter of the opening on the end of the tube depends upon the size of the float used, and the column of water supplying the laboratory: 1 to 2 millimetres I have found sufficient for all purposes; and, with the larger float mentioned, an opening of 2 millimetres can be used with a street pressure of over one hundred and fifty feet, and supply twenty, thirty, or more water-baths.

In placing this regulator in the laboratory, the best place to put it is over the sink, or other convenient place, to allow for the running off from any overflow that might possibly occur. The upper tube on the side of the vessel is so arranged, in regard to height, that an overflow will take place a little below the maximum level of the water-baths.

With this description and the drawing, the character of the instrument and manner of using it are readily understood. The upper end of the glass tube is conveniently connected with any reservoir in the laboratory, or with the street pipes, and the float in the instrument regulated.

One advantage which this regulator has over that of Bunsen is, that the latter has to be made of glass, and that mercury is required; but the principal advantage is that Bunsen's can only be used with a head of water a few feet high, whereas the regulator just described can be directly attached to the water-works of any city. I have no instrument in my laboratory in constant use which gives me more satisfaction than this.

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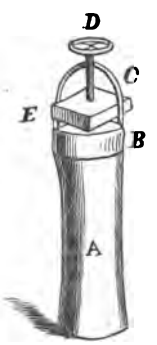
9. A CONVENIENT FORM OF SPECIFIC GRAVITY FLASK. By J. LAWRENCE SMITH, of Louisville, Ky.

A MEANS of readily testing the specific gravity of solid bodies with close accuracy is much desired by those engaged in mineral chemical research. The little apparatus I have been using for some time is admirably adapted to this end, giving excellent and speedy results. It is nothing but a modification of the specific gravity bottle; so constructed, however, as to use a very small amount of water, and to enable large pieces of the substance to be introduced into the flask, closing the latter with a ground plate instead of a stopper.

The apparatus as figured will explain itself at once. *A* is a medium stout tube, about 13 millimetres inner diameter, and about 7 or 8 centimetres long, with a piece of glass about three millimetres thick, ground smoothly and flat, to lie well on the top of the flask, which is also ground. A gallows screw arrangement, *B C D*, is made of brass or other metal (the one I use is of platinum), quite light, so as to fasten down gently the plate, *E*, when required. The band, *B*, fits tolerably closely to the flask, leaving room enough for good red sealing-wax to fasten the same. After introducing the water, and the substance whose specific gravity is sought, the flask is dried thoroughly with a piece of filter, without handling it too much so as to affect the temperature of the water. Of course, all the specific gravities are taken as near 60° Fahrenheit as possible, or they are corrected for difference of temperature.



10. On Bending Glass Tubes for Fitting Apparatus. By J. Lawrence Smith, of Louisville, Ky.

It is well known that it requires some tact to bend a tube with an even curve and without collapsing its sides, and many chemists never do succeed in bending them skilfully. Although having no particular skill in this matter, I never fail to bend them perfectly satisfactorily, by using a flame different from the one usually employed. The flame is one given by the Bunsen burner, described in my article on Alkali Determination in Silicates. (See "American Chemist," vol. i. p. 407.) The burner is very commonly used now in all laboratories, where the extremity of the burner is flattened out so as to give a short and thin but broad flame, something like the flame of an ordinary gas-burner. The tube is placed in this flame, and turned round and round until a good heat is given to the tube. It is then withdrawn from the flame, and bent, when it does so with a perfect curve, and with no collapse of the sides of the tube. Of course, this is only intended for the smaller tubes; but a tube of 1 centimetre and more can be thus bent very readily.

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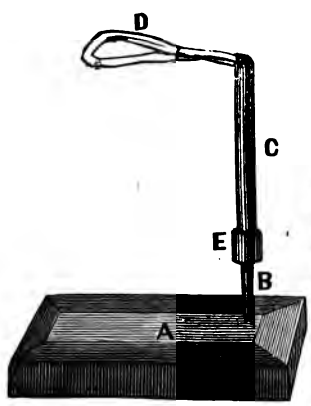
11. A Simple, Clean, and Convenient Little Stand for Small Filtrations. By J. Lawrence Smith, of Louisville, Ky.



This consists of a base of wood, *A*, well oiled with linseed oil. In this insert a piece of glass rod or stout tube, *B*, and fasten the same, in any convenient manner, by sealing, wedges, or otherwise. The tube is of a size to slide easily into a brass tube, *C*, of about 1 centimetre inner diameter, and 4½ inches long. On the lower end of the brass tube is slipped a piece of stout gum-tube, *E*, about 2½ centimetres long, that will clasp with a little pressure the glass tube, *B*. In the top of this is fastened a glass triangle, *D*.

The movement of this stand is very easy; and, as the funnel-support is always at the top, there is no rod to interfere with the pouring of the liquid on the filter from any point. It is well to make a mark round the glass rod with a file, about three-quarters of an inch from its upper end, and fill the mark with a little black or red wax or paint, so that the operator may readily see to what extent he can raise the brass tube.

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12. STEAM-BOILER WATERS AND INCRUSTATIONS. By JOSEPH R. ROGERS, of Madison, Indiana.

THE importance of a scientific consideration of this subject has always been felt by practical engineers, yet little or nothing has as yet been done towards familiarizing users of steam with those physical and chemical laws which bear so important a relation to the subject. In the absence of this knowledge, a great number of means have been devised for obviating the difficulties attendant upon the use of hard waters for steam purposes. These, however, have uniformly been of a crude, empirical sort; achieving, at best, only a very imperfect success, and often doing more harm than good. In offering this paper before the Association, the writer desires to present a brief *résumé* of the various proposed methods of scale-prevention, together with some investigations of his own; hoping that such attention may be attracted to the subject as its importance demands.

All waters used in steam-boilers contain, in solution or suspension, more or less mineral matter, acquired by contact with the earth's surface or by percolation through its alluvium and rocks. Of this, sea-water contains about 2,500 grains in the gallon, in solution; river and lake waters, from 5 to 20 grains in solution, and a varying quantity in suspension, generally exceeding 10 grains. Well and spring waters hold but little in suspension; but, in solution, a quantity varying from 10 to 650 grains. This mineral matter consists of a variety of substances: the carbonates of lime, magnesia, and iron; chlorides of calcium, sodium, magnesium, and potassium; sulphates of lime, magnesia, soda, and potash; phosphate of lime; bromides and iodides of calcium and magnesium; alumina and silica. Be-

sides these mineral substances, more or less vegetable matter is found, which is derived from the same source. Certain gases are, also, more or less present. These are oxygen, nitrogen, carbonic acid, and sulphuretted hydrogen; the first three being always found. Very rarely, salts of nitric and nitrous acids exist in the waters of wells in certain localities. All of the above substances are not uniformly found. The quantity and character of the mineral matter in any particular water depend much on the constitution of the earths and rocks over which or through which it has passed, and upon the various conditions of location, motion, and exposure to light, heat, and air which it has undergone. Consequently, there is much variety in the constitution of various waters, with reference to their adventitious ingredients. Upon this variety depends the variation in their adaptability to use in steam-boilers. All water, on being evaporated by boiling in an open pan, leaves a residue, composed of all the mineral matter contained in it. The deposit of this residue takes place in the following way: As soon as ebullition begins, the free gases are driven off, not being soluble in boiling water; and as the presence of carbonic acid is necessary to the solution of the carbonates of lime, magnesia, and iron, these salts, which are found in all waters, are precipitated in a finely crystalline form, tenaciously adherent to whatever they fall upon. Sulphate of lime, which is commonly present, is soluble in 400 parts of cold, but scarcely at all in boiling water; therefore, as the evaporation proceeds, supersaturation occurs, and this salt is thrown down in the same form, and possessing the same adherence, as the carbonates. The other contained elements, which are more soluble, are precipitated in the same way by supersaturation as the quantity of water is lessened. The suspended matter gradually subsides, and agglutinates with the other deposits. In a steam-boiler, the deposit from the evaporated water tends to take place in the same manner; but the constant supply of fresh portions, and the occasional emptying out of the saturated water, prevents the precipitation of the more soluble salts, and these are retained in solution. Practically, it is found that the deposits from all kinds of boiler-waters consist almost entirely of the carbonates of lime, magnesia, and iron, and the sulphate of lime. Scarcely more than 5 per cent. of other salts are found. In marine boilers, a mushy residuum of chloride of sodium is precipitated sometimes, but incorporates itself only to a slight extent with the agglutinated incrustation of the above-mentioned salts.

This latter deposit gradually accumulates, unaffected by the force of the boiling currents, becoming thicker and harder till, if not removed, it becomes as dense as porcelain, and much tougher. Under the influence of high heats, this scale is often converted into absolute glass by the combination of the silica, deposited from suspension, with the bases of the carbonates.

The evil effects of scale are due to the fact that it is relatively a non-conductor of heat. Its conducting power compared with that of iron, according to Despretz, is about as 1 to 37.5. Accordingly, more fuel is required to heat water through the shell and flues of an incrusted boiler than would be required if the boiler were clear of scale. It is readily demonstrated that a scale $\frac{1}{16}$ of an inch thick will demand the extra expenditure of about 15 per cent. more fuel. The ratio increases as the scale grows thicker. Thus, when it is $\frac{1}{4}$ inch thick, 60 per cent. more fuel is needed; when it is $\frac{1}{2}$ inch thick, 150 per cent.; and so on. The crust sometimes becomes so thick as to prevent a sufficient heating of the water by the burning of any amount of fuel that can be placed in the furnace.

If a boiler be perfectly clean, the contained water may be raised to any given temperature by heating the external fire-surface to a temperature a few degrees higher; but, if scale be present, it will be necessary to heat it still higher, according to the thickness of the scale, in an increasing ratio. To illustrate: To raise steam to a pressure of 90 lbs., the water must be heated to 320° Fahr. If the boiler be clean, this may be done by heating the fire-surface to about 325°; but if $\frac{1}{8}$ an inch of scale intervene between the shell and the water, such is its non-conduction that it will be necessary to raise the fire-surface to a temperature of about 700°, — almost low red-heat. Now the higher the temperature at which iron is kept, the more rapidly it oxidizes or carbonizes, and undergoes molecular change. At any temperature above 600° it soon loses the fibrous nature of wrought-iron, and becomes granular like cast-iron, which it has really become by carbonization. In this condition it is brittle, thin, and under high heats liable to bulge or even give way to the great pressure upon it. Weakness of the boiler thus induced predisposes it to explosions, and makes necessary expensive repairs. Another evil resulting from the presence of scale is that it renders slower and more difficult the raising, maintaining, and lowering of steam.

To obviate these evils, — namely, danger from explosion, ex-

pense of repairs, loss of time, and waste of fuel, — very many methods have been devised having in view the prevention and removal of scale. For this purpose, picking, scraping, chaining, &c., are generally resorted to periodically. Such is its toughness and tenacity, however, that mechanical force only succeeds in removing a portion of it, and is generally unsatisfactory; since, in addition, it is necessary to empty the boiler, and allow it to get cool enough to enter; which, with the operation itself, generally requires a whole working-day. Various mechanical contrivances have been and are now used to intercept the precipitated saline matter from the supply-water on its passage through the heating-apparatus. They consist, essentially, of a series of obstructions to the flow of the water; this latter being heated to boiling by being intermingled with the exhaust-steam in the heater, the carbonic acid is driven off, and a precipitation of the carbonates takes place; the deposit accumulating on the shelves, straw, or other obstructions over which the water slowly flows. In this way, large accumulations of the matter in suspension and of the precipitated carbonates are prevented from going into the boiler; and, being retained in the heater, may be removed very conveniently when opportunity is afforded. This plan, however, only partially remedies the difficulty, since it is only the precipitated carbonates and the matter in suspension that is retained by the apparatus. The soluble salts all pass on to the boiler, and also a great portion of the earthy carbonates, which cannot all be precipitated during the short passage through the heater. The scale in the boiler more slowly, but as surely, forms. Another variety of mechanical device for preventing scale is the sediment-pan. This — of which there are many forms — consists, essentially, of a shallow vessel which is placed in the bottom of the boiler with the view of catching the precipitate, and preventing its deposition on the inner surface of the shell. It is removed at intervals, and cleaned. This plan succeeds in gathering much of the sediment; but much, necessarily, fastens itself to the boiler; and the scale, as before, continues to form. It is impossible to make any mechanical contrivances completely efficacious. The great *desideratum*, perfect prevention, cannot be attained by any mechanical means: to chemistry alone can we look for a complete method.

For a long time, simple chemi[illegible]ve been used, in an empirical way, with a [illegible] these, and their *modus operandi*, I w[illegible] slops, vinegar,

cane-juice, and a variety of vegetable substances, containing more or less acetic acid, when placed in the boiler at regular intervals, will remove and prevent the incrustation to a certain extent. The acetic acid decomposes the carbonates, forming acetates, which are kept in solution, and hence cannot become increments of scale. The sulphate of lime and other salts are not affected by it, and from these the scale will gradually be formed. Moreover, the iron of the boiler being open to the attacks of the free acid, it will be gradually corroded, and after a time rendered useless, if not dangerous. This fact alone ought to forbid the use of these agents. Starchy matter, in the various shapes of potatoes, corn, oil-cake, &c., has been much used. These prevent scale only by enveloping the precipitates with gelatinous matter, which lessens their weight and prevents their agglutination into a solid mass. Starch, as well as nearly all other organic matter, has a tendency to produce frothing of the water in the boiler, in which case the exact quantity present cannot be determined by the gauge-cocks. This is a source of great danger, and ought to prevent the use of such agents. Oak, hemlock, and other barks and woods, are operative in the prevention of incrustation, on account of the tannic acid which they contain. Various extracts, such as catechu, logwood, &c., rich in tannin, are also used. Tannic acid decomposes the carbonates, forming tannates, which are insoluble; but, their specific gravity being light, they do not subside, but remain continually floating in the boiling currents; and moreover, being amorphous, they have no tendency whatever to agglutination, and therefore do not incrustate on those surfaces with which they come in contact. The sulphate of lime, however, is not decomposed by tannin, and will form a scale notwithstanding its presence. The same objection holds against tannin in its free state, as offered in the above-named agents, as does against free acetic acid. It will attack the iron of the boiler; though, as the tannate of iron is insoluble, the corrosion will not be as rapid as with the acetic acid, which forms a soluble acetate with iron. The fixed alkalies are much used in the various forms of lye-ashes, sal-soda, caustic soda, potash, &c. These agents decompose the sulphate of lime; the resulting sulphate of soda or potash being retained in solution, the carbonate of lime being precipitated, but in larger crystals not so apt to condense into hard scale. The carbonates of lime and magnesia held in solution by free carbonic acid are precipitated by the appropriation of this acid, to form carbonates

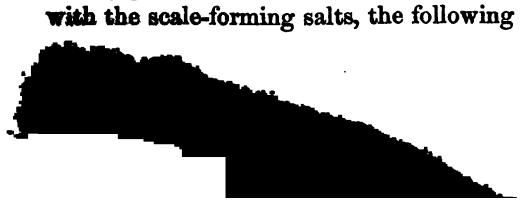
or bi-carbonates of soda or potash; but, as with the sulphate of lime, the crystals being large do not form so refractory a scale as when precipitated by boiling alone. Still, as these earthy carbonates form the major part of nearly all incrustations, this method, which fails to do more than merely modify their form and qualities, without affording means for their avoidance, deserves little attention. Ammonia and its carbonate have a precisely similar action, and are similarly objectionable. These alkalies have no corrosive action on the boiler; but rather, on the other hand, tend to prevent it, by appropriating the free carbonic acid, which ordinarily combines with the insoluble crust of oxide of iron on the inner surface (rust formed by contact with the water), forming a soluble carbonate, which, being constantly dissolved away from the iron, leaves a surface always exposed to fresh action.

Muriate of ammonia is another means of prevention. This has its action only on the earthy carbonates. The resulting carbonate of ammonia, being volatile, passes off with the steam, and the chlorides of calcium and magnesium are retained in solution. This is a very efficient way of removing old scale, since the earthy carbonates, as before stated, constitute the greater portion of most incrustations. Its only objection is the ammoniacal odor in the steam. Petroleum has been used with some reported success. The *rationale* of its action is difficult to explain, owing to its chemical complexity.

The foregoing are methods in which a single agent is depended on. Many compounds have been devised with a view of overcoming all the difficulties, which no one agent can accomplish. Many such have been patented; and many more are sold as secret, proprietary preparations. Tannin is the base of most of them, generally in combination with various alkaline salts and some starch-bearing substance. These elements, some useful and some useless, I have found nearly always in a state of mere mechanical mixture, without any definite chemical constitution. The tannic acid is uniformly in excess, — which circumstance is very objectionable on account of danger of corrosion; and there is always an amount of inert, insoluble, vegetable matter, which is very liable to cause foaming. Besides these methods in which chemical agents are put directly into the boiler, others have been devised in which the waters are depurated in tanks before entrance into the boiler. Clark's method consists of the admixture of lime simply. This precipitates the earthy carbonates by appropriation of the free carbonic acid, which holds them in solution. The newly formed car-

bonate of lime, being insoluble without the presence of free acid, also falls. The supernatant water is drawn off for use. Sulphate of lime and other salts remain untouched. This in turn might be removed by carbonate of soda; carbonate of lime being precipitated, and sulphate of soda being retained in solution. Another method proposed by myself consists, essentially, in the conversion of the earthy carbonates into soluble chlorides by hydrochloric acid; the excess being neutralized by filtration through carbonate of baryta — witherite — in coarse powder. The soluble chloride of barium thus formed will decompose the sulphate of lime; the resulting chloride of calcium being very soluble, and the sulphate of baryta insoluble and very heavy. The latter subsides, forming a deposit not easily disturbed. By this method, the carbonates of lime and magnesia and the sulphate of lime, which constitute 95 per cent. of the scale-forming matter, are completely changed into very soluble chlorides, which will not form a scale under any circumstances. This plan recommends itself for railway water-stations by its cheapness and simplicity. Tannic or acetic acid — the excess being properly neutralized by carbonate of soda — may be also used for tank-depuration. With the tannin, insoluble tannates are precipitated; with the acetic acid, the carbonates are converted into soluble acetates. The neutralizing alkali will decompose the sulphate of lime, producing soluble sulphate of soda, and precipitating carbonate of lime. The carbonate of soda or potash alone may be used, as it will precipitate all the lime and magnesia as carbonates. All these tank-methods require supervision, and cannot to any great extent influence scale already formed; and, as the removal of this is as needful as its prevention, it is palpable that, for general application, that method is best which attains the complete removal, as well as prevention, of scale by chemical means operating inside the boiler.

As fulfilling this indication with ease and economy, and without damage to boiler, foaming, or other untoward result, the writer has devised the following process, which three years of extensive and varied practical trial have thoroughly tested. Tannate of soda is the agent used. This is periodically introduced into the boiler or heater, by any convenient means, in sufficient quantity to maintain a constant excess, determined by the presence of its peculiar color in the water at the gauge-cocks. It is soluble, and being constantly present in the boiler, as the supply-water pours in loaded with the scale-forming salts, the following reactions are constantly



going on: Between the tannate of soda and the carbonates of lime and magnesia a mutual exchange of acids and bases occurs; the lime and magnesia being precipitated as tannates, in a light, flocculent, amorphous form, so that they do not subside at all, but are kept circling in the boiler-currents, until they find their way into the mud-receiver; there finally subsiding into a loose, mushy sediment, which may be blown away very readily, from time to time, as it accumulates. The carbonate of soda formed in the reaction is retained in solution, becoming a bicarbonate by appropriation of the free carbonic acid of the water. This decomposes the sulphate of lime. The resulting sulphate of soda is retained in solution, and the carbonate of lime is acted upon at the moment of precipitation by fresh portions of the tannate of soda. The constant presence of the alkali protects the iron of the boiler from all action whatever, either of tannic or carbonic acid, since both have a greater affinity for soda than for iron. The alkali will keep both acids neutralized as far as the metal of the boiler is concerned. The lime and magnesia however, having a greater affinity for the tannic acid than the soda has, its acid action will be operative on these bases, producing the results before detailed. The same reactions take place between the tannate of soda and the already formed incrustation. Its exposed surfaces are gradually disintegrated, the resulting sediment finding its way to the mud-receiver. This superficial abrasion gradually loosens portions of the scale which should be removed at intervals of from one to four weeks, according to circumstances, until the boiler is clear, after which it will only be necessary to open the boiler at long intervals for inspection, as the tannate of soda will keep it clean if properly used in sufficient quantities. As the earthy carbonates and the sulphate of lime constitute the great mass of the mineral matter found in most boiler waters, and as the remaining constituents are soluble, and hence do not incrustate if the boiler is occasionally emptied, it will be seen from the foregoing that in this salt, the tannate of soda, we have an agent which perfectly fills the demand theoretically; and, as before stated, extensive trial in all kinds of boilers and all kinds of waters has proven its practical efficacy. It is applicable to marine boilers as well as to those using fresh water; for the marine incrustation is almost precisely similar to that formed from the waters of rivers, lakes, &c., consisting, as it does, principally of earthy carbonates and sulphate of lime. The chloride of sodium of sea-water forms a mushy deposit, if supersaturation is

allowed to take place; but it is incorporated in the scale only to a slight extent, and this is generally prevented by more or less constant change of water, by blowing out both from the surface-valve and from the sediment-receiver.

The length which this paper has already reached forbids my noticing several other methods of scale-prevention, which have been proposed by myself and others; but, before leaving the subject, I will mention a simple method of determining the hardness of waters and their fitness for boiler use. A saturated, filtered tincture of soap is prepared of proof spirit and the soft soap of the pharmacopœia; also a solution of bicarbonate of lime, by passing carbonic acid gas through lime till it becomes clear. An ounce of this is carefully evaporated, and the residue weighed. To another ounce of this solution the tincture of soap is added, one minim at a time, with shaking after each addition, until a permanent lather is formed. The weight of the above residue in grains is to be compared with the number of minims required to produce a lather. This comparison will show how many grains of hardness will be neutralized by a given number of minims of the soap tincture. The tincture, thus roughly titrated, is to be added, one minim at a time, with constant shaking, to an ounce of any water, until a permanent lather is produced. The number of minims required will indicate by reference to the last operation the number of grains of hardness. Tincture of soap does not alter when kept closely stopped; and by this simple agent, with no other apparatus than a minim glass and a vial, the hardness of any water may be determined with sufficient accuracy to decide upon its fitness for boiler use.

III. PHYSICS OF THE GLOBE.

1. Contributions to Physiographic and Dynamical Geology, involving the Discussion of Terrestrial Magnetism. By Richard Owen, of Bloomington, Indiana.

In offering some new facts bearing on the above subject, perhaps it is admissible previously to call to mind a few established facts, particularly astronomical, which have more or less recently been promulgated:—

1. That sometimes the earth's greatest proximity to the sun occurs in our winter, sometimes in our summer: thus about 4000, B.C., perihelion was on the 20th of September; and in 1864, A.D., perihelion was the 1st of January.

2. That the sun has at present more duration of power by seven or eight days in our combined spring and summer than in our combined autumn and winter; 850,000 years previously this difference amounted to fifteen days, giving the northern hemisphere relative advantage in land forming, if the magnetic law hereafter indicated is admitted.

3. General Sabine found the dip increase with the proximity of the earth to the sun, and *vice versâ;* this proximity may coincide with our winter or with our summer; at present with the former.

4. The periodical change in the form of the earth's orbit from an ellipse to a figure almost circular must further modify the proximity chiefly dependent upon the earth's place in her orbit.

5. We must bear in mind that the ecliptic, at one period, formed an angle with the equator at least as small as $22\frac{1}{2}°$, the fourth part of 90°.

6. Humboldt's objection to supposing currents of electricity to move around the earth arose from his finding that solar heat did not penetrate to any very considerable depth in the soil; but he himself suggests, since the discovery made by Faraday, that warm oxygen is diamagnetic, that the electrical currents may exist in the air. It will be shown afterwards that these probably move also along earth molecules which arranged themselves parallel to the ecliptic during the consolidation of land.

7. Fourteen years since I demonstrated, in "Key to the Geology of the Globe," published in Nashville, Tenn., that most extra-tropical continents, or extra-tropical parts of continents, exhibited coast lines and mountains having a general trend of 23½° east or west of the terrestrial poles; while inter-tropically the coast lines trend 23½° north or south of the equator.

In enumerating some recently observed facts carrying out more fully the above law, after testing it by many more coincident facts than the time usually allotted would permit me to set forth in detail, I shall confine myself to the most prominent, and arrange them under: —

I. Terrestrial Magnetism.

Perceiving that the coast lines of continents coincided with the terminators of some phase of the ecliptic, and other portions in the interior of the V-shaped land were marked by the secondaries of the ecliptic, while the central, straightest, and most elongated, were at right angles to the equator, it seemed impossible to avoid the conclusion that the sun had a more or less remote influence in giving form to the land.

It was soon, however, further observed, that the greatest heat coincided with the solstices of certain phases of the ecliptic; that all the known localities of gems (generally supposed to result from crystallization under electrical influence) could be traced along two special phases of the ecliptic, and that the secondaries of these ecliptics marked very important coast and mountain lines, great circles of heat, chemical and volcanic action, &c. Also, that under some of these had been raised, within the historical period, large tracts of country, as along the Andes, in Sweden and Finland; also islands, as Reguain, Santorini, Graham's Island, &c., while other portions not under those lines were sinking, as Greenland, north of latitude 69° north, which is north of the terminator. All these and many other coincidences forced the conviction that the sun, at least at the solstitial periods, must by thermal difference generate currents of electricity, probably in the oxygen of the air, and in the diamagnetic earth molecules.

This would at once account, as Ampère showed, for the magnetic needle arranging itself at right angles to those currents; and if magnetism can expand the earth's crust, then we see why the land was elevated along the secondaries. But if it be denied that magnetic impulses are sufficient to produce these phenomena, then

we have only to consider magnetism converted into its other phase, chemical action, with the development of gases, the fusion from solidity, or the solution in hot water of metallic and earthy ingredients, the expansion power not only of the gases, but of the other phase heat, transmitted to the yet inert masses; and we certainly have, as far as human eye can penetrate in this subterranean laboratory, all the conditions fulfilled for bringing about the effects we observe on the surface.

If, then, we admit magnetic phenomena as modifying directly or indirectly the earth's structure, we are next led to inquire what peculiar modifications are connected with the magnetic phases of Intensity, Dip, and Variation. These will be briefly alluded to in the above order.

Intensity.

A great circle, passing close to the coast of Brazil, passes through one of the foci of intensity as laid down by Mrs. Somerville, and, continued into the opposite South Pacific, passes also through, or close to, the focus of greatest intensity as laid down by Humboldt and Mrs. Somerville. If we construct an ecliptic which shall have its solstices immediately north and south of this weaker South Atlantic focus, we have an ecliptic which, especially during our winter, when perhaps that season coincided with perihelion, exhibits great intensity and electrical power, either residuary from a former period, or now existing, as indicated by the foci of its secondary, or perhaps both combined. To prove this, let us trace it through Brazil, where the emeralds and diamonds are found, next near Cape Comerin and Ceylon, the region of diamonds and sapphires, to the ruby locality between Birmah and Siam. The only other noted gem localities can be found under, or near, an ecliptic of next greatest intensity, whose solstices are found due north and south of the centre of land, centre of motion, and, evidently, centre of the whole magnetic system. It traverses, if we follow *both* semi-annual declinations, the diamond region of Brazil, South African diamond locality, and diamonds of India, and embraces between its converging lines the diamond region of Borneo.

The secondaries for the solstices of maximum intensity arise respectively from nodes on the equator, just east of Africa and north-east of the Marquesas. The former, which are the stronger, define the north-east coast of Africa along the Red Sea, through Hungary and Prussia, to Iceland and Greenland, where its east

coast intersects the arctic circle. This is exactly 90° from both the nodes just spoken of, for which reason, and because it is antipodal to Sir J. Ross' magnetic south pole, but more especially because all the seventy-four observations for declination laid down around the globe (as given in Lardner's "Natural Philosophy," p. 208) converge in their variation to this point, except a few drawn aside by the magnetic pole of dip, we must consider the Greenland arctic pole as the pole of greatest intensity. This terminator further passes through the Hudson Bay focus of intensity, while its mate passes through the Siberian focus. Intensity thus appears due to combined proximity of the sun, and greatest solstitial power.

Dip.

If we trace the equator of dip according to the best authorities, it is found to undulate between the two ecliptics just described, and to intersect them where they intersect each other, vertically in the western hemisphere, under Sir J. Ross' north pole of dip; in the eastern hemisphere, due south of the Gulf of Obi, in which, about latitude 70° north, there seems, as was suggested by Hansteen, to be an Asiatic north pole of dip, and, I may add, perhaps also an Asiatic north pole of intensity on the arctic circle, 180° from Greenland. These have probably south poles. Indeed, the antipode of the Gulf of Obi is laid down by Humboldt as a point indicated by Ross as having magnetic importance (see "Cosmos," Longman's edition, vol. iv. p. 97). Dip, then, seems that phase of magnetism connected with equilibrium, between the ecliptics of intensity, — perhaps between perihelion in our winter and perihelion in our summer.

Variation or Declination.

The whole magnetic system is known to move slowly and periodically; at present that movement is from west to east in the northern hemisphere, while in the southern the motion is from east to west.

If we consider the African node, where the centre of motion, centre of dip, centre of land, and solstitial meridian of intensity No. 2, all intersect, as the centre also of magnetic oscillation, and permit the secondaries to vibrate to their supposed extremes, viz., 16½° each side of the terrestrial north pole, we find the western secondary following important coast lines, and, not only passing through the Greenland pole of intensity, but through the Boothia

Felix pole of dip and the south pole of intensity. Trace now the eastern secondary, and we find it marking the Gulf of Obi pole and its antipodes, besides slightly deflecting the northern part of the Ural Mountains, which in the rest of their course conform to an equinoctial secondary; being directly over the east African node of ecliptic intensity No. 1. The variations for Paris, taken from A.D. 1580 to 1835, as given by Lardner, p. 210, are measurably accounted for on the supposition of this oscillation occupying perhaps 300 years or thereby, while the intensity vibrates, or changes from the one secondary to the other, in accordance with the predominance of electricity in one ecliptic or the other; the dip, however, varing also in connection with perihelion and aphelion.

Horary and Semi-annual Variations in Declination.

If strong additional evidence were required to show that the sun's electricity caused the position of the needle, it is found in the two facts. 1. That the needle every day has a slight variation from soon after average sunrise to soon after his reaching the meridian of any given locality; the currents evidently approaching the needle in a somewhat different plane, as modified by refraction or other causes, from the plane assumed at noon; and that there should be slight reaction in the afternoon, when the warmer molecules are *west* of the colder, instead of being east of them, seems natural. 2. The second is that the needle, besides, varies six months in one direction, and, changing at the equinoxes, exhibits variation for six months in the other direction. That the semi-annual variations in declination should be different in the northern and southern hemispheres, and change at the equinoxes, is readily understood; but why St. Helena, in about latitude 15° south, and Singapore, about 2° north of the equator, should partake half the year of the perturbations peculiar to the northern hemisphere, and during the other six months of perturbations peculiar to the southern hemisphere, was not comprehended; it is however at once explained when we observe that the former place is situated on the Intensity-Ecliptic No. 1, the other on Intensity-Ecliptic No. 2

Disturbance Variation.

As there is a residuary power in the paramagnetic molecules (which in the Rocky Mountains prevents the use of the magnetic needle, and compels the employment of Burt's solar compass), and

as the direction of magnetic impulses would be north-west in the Rocky Mountains, while in the Appalachians, or even at Toronto, it would be north-north-east, although both sets of impulses start from near Chimborazo, it is easily seen why, as Point Barrow is near one secondary, and Toronto near the diverging secondary of the other solstice, the so-called disturbance variations, although occurring simultaneously, should yet have opposite phases.

Agonic Lines.

There is no variation at all points centrally between these diverging secondaries, namely, along the secondaries of the equator; the needle, setting itself at right angles to the equinoctial plane, points to the terrestrial north and south pole. These agonic lines occur chiefly at the meridians of the ecliptic nodes, but are found more or less every 45° east and west of the West African node, which may be termed the prime magnetic meridian.

II. Geology and Physical Geography.

The facts, recently observed, bearing on this second subdivision of the subject, are chiefly these: —

Along the ecliptics prevail mostly those chemical effects, such as the crystallization of carbon into diamonds, &c., as well as regions of greatest heat, and the upheaval of the second highest mountains; while along the secondaries we find abundant evidence also of heat at the geysers, linear hot springs, linear volcanoes, Gulf and Japan streams, &c., as well as chemical action in erupted molten rocks, liquid mud, gases, and the like; and also mark the rise of the Himalayas.

The divergence of two terminators, south-west of South America, seems the probable cause why the tidal wave, instead of entirely following the moon, here separates.

The heat of the Scandinavian terminator may account for the melting of the icebergs and the dispersion of drift from that region, and the activity of the geysers in Iceland; while a secondary of the other ecliptic has given warmth to the region of the Lena. Vital energy seems to have been imparted to vegetable and animal life by the magnetic impulses, chiefly of these solstitial secondaries, as near them we find the giant Lequoias, the ancient monsters of Nebraska, of the Pampas Plain, of Siberia, and the Urals.

The land on the globe is to the water as 66 or 67 to 180 (the former without the Antarctic continent), and in accumulating in the northern hemisphere (probably because proximity agreed with our winter intensity when paleozoic land was forming during the prevalence of intensity-ecliptic No. 1), it has extended itself chiefly from the Tropic of Cancer to the arctic region. Africa forms an exception, for that continent has accumulated as land around the central intersection of the terrestrial and dip equator in such manner that the Mediterranean is nearly 33° north of the node, and the Cape of Good Hope is a somewhat greater distance south,— together 66° or 66½°, — while the width of Africa, from Cape Verde to Cape Gardafui, is also 66°. The length of North America and of South America, as well as of Asia, from her northern shore to Cape Comerin, also measures 66°; indeed, the length and breadth of all land is found to be some dividend of that number.

Sixty-six and a half degrees being the complement of the ecliptical angle, or, in other words, this being the angle which the earth's axis forms with the plane of the equator, the land would naturally assume those dimensions, as well as the rhomboidal shape, which several continents have, with the centre angles pointing in a northerly and southerly direction, if the sun caused its development. As an interesting corroboration of this law, that the sun gives form and dimensions to the land, let us take with compasses the distance from Cape Comerin (where the greater intensity ecliptic is found) to the north coast of Asia, and moving one foot of the compasses, thus extended, along the north coast, either east or west, the other foot will be found to correspond to one or other ecliptic. This appears to indicate that the magnetic effect is powerful about 66½° north of the electrical current, inducing strong terrestrial magnetism at that distance, although the poles are 90° from the equator, measuring on the secondaries.

The chief deposits of the paramagnetic metals, especially when nearly or quite pure, connect north and south; while those of some diamagnetic metals, gold at least, can be traced along parallels of latitude. Time has not permitted a full investigation of this practically useful branch; but I may mention that while the chief deposits of coal are found along, or parallel to, the solstitial secondaries, those of petroleum and bitumen are near those (and perhaps across one, as in Pennsylvania), but are connected by lines which are secondaries to the equinoctial plane, such as the great circle passing from New York and Pennsylvania through Virginia and North

Carolina, Cuba and Jamaica, New Granada, Burmah, Lake Baikal, &c. Trinidad, however, is nearly under an ecliptic, and the Baltic, where amber is common, under one of its secondaries. The Caspian Sea bitumen is under an equinoctial secondary.

We must now, reserving further details for future discussion, hasten to the

Summary.

A vast number of coincidences are fully explained, if we admit the law that solar influence indirectly has caused the phenomena to which Humboldt, in his immortal "Cosmos," gave the name "Reaction of the interior of the earth on its exterior." Add to this the fact that the whole is strictly in accordance with the correlation of forces, and throws much light on the hitherto unexplained phases of terrestrial magnetism.

Much, then, as theorizing is sometimes to be reprehended, and generalization, without sufficient facts, to be condemned, probably every scientific man will agree that (as here no favorite theory was started with, but facts were collated until they pointed to a law) we are justified in following up this interesting glimpse into the arcana of Nature, and in admitting as a general law that which embraces the whole array of coincident facts, beautifully explaining many phenomena, and pointing us to the conclusion which every year, as science advances, is more powerfully set forth to our observing and reflecting faculties, that there is uniformity and simplicity in the great plan of creation. If the law is admitted, it would bring us to something like the subjoined conclusions: —

1. The sun is the source of the modifications on the earth, giving the form and dimensions of the land: operating through some of the phases or modes of motion, which we embrace under the names light, heat, electricity, magnetism, vital force, and probably nervous energy.

2. By thermal agency ecliptical and equatorial currents are generated chiefly from east and west, from the hotter air and earth molecules to the cooler, each afternoon, however, producing a slight reaction on the same principle.

3. These currents generate magnetism at right angles to themselves, namely, along the secondaries of the ecliptic in all its phases, although most strongly at those of the solstices, and also along the secondaries of the equator, which are meridians, especially at

every 45° apart, beginning east and west from the prime magnetic meridian.

4. The electricity of the ecliptics has produced heat and crystallization, while the magnetism of these secondaries, either directly, or by conversion into chemical force, has developed the land, called forth the metals, stirred the volcanoes into activity, heated the geysers, the ocean currents and the hot springs, modified the climate at different meridians on the same parallels, caused the tidal wave to diverge, perhaps melted the glacier ice that held the drift boulders, stimulated vegetation, and gave energy to animal life.

A field is thus opened for further investigation, which pertains, not to the geologist and mining engineer alone, however important to them, but also offers labor full of interest for the astronomer, in defining accurately the modifying periods of greatest heat, light, electricity, magnetism, &c., in connection with the precession of the equinoxes, proximity of the sun, solar spots, form of the earth's orbit, &c.; for the physicist, in confirming and classifying the observations connected with terrestrial magnetism; for the physical geographer, in tracing his orology, courses of rivers, wind's currents, electrical and seismographic phenomena, also the distribution of plants and animals, as well as the distribution of heat and rain, pursuing these researches with hereby increased light and vigor; while to the naturalist, the anthropologist and historian, or student of the philosophy of history, there is furnished ample food for reflection.

Finally, above all, these sublime developments should stimulate us with fresh desire to understand more fully the beautiful and immutable laws by which the Divine Ruler holds the universe in harmonious action; and should cause us to increase our endeavors ever to live in accordance with those divine laws.

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2. Account of a Dust-Storm of December 24th, 1870, in Clinton County, Indiana. By Joseph Tingley, of Greencastle, Indiana.

On the morning of December 25th, 1870, the attention of the citizens of Clinton County, in the State of Indiana, was attracted

by the unusual appearance of a thin layer of dark-colored substance lying upon the surface of the snow, with which, at that time, the greater portion of the State was enveloped.

During the night of the 24th, there had fallen a light, feathery snow, which, by its collection upon the western side of buildings and fences, showed that the wind at the time was westerly. The dark-colored substance was evidently a travelling companion with the snow, since it was observed to be commingled therewith throughout; and, in places where the accumulations of snow-drift were greatest, the foreign substance was most abundant.

The district covered by the commingled snow and ashes (for such it proved to be) embraced at least all that portion of the State lying within a circle of twenty miles radius, of which the town of Frankfort is the centre.

There is reason to believe that its extent was really much greater, as traces of it were observed in Putnam County, at a point distant from Frankfort about fifty miles.

The quantity of the substance was very great. I have in my possession the product gathered from an area of three yards square. It weighs twenty-six grains.

If distributed, in the same abundance, over the whole surface of the district described, the whole quantity which fell must have amounted to 600 tons.

The material presents the following character: A vial, in which the melted snow and its dark-colored companion were allowed to remain in contact for a month, gave a strong odor of sulphide of hydrogen. A chemical examination proves that more than one-half of the material is organic.

But the microscope gives more satisfactory evidence of its true nature.

A portion was submitted to a microscopist connected with the Smithsonian Institution, who found it to contain "fragments of vegetable tissue, embracing the epithelium and parenchyma of leaves, vegetable hairs, dotted and spiral ducts, woody cells, and a few elongated cells with the characteristic circular markings of the conifera. There were, besides, a great number of angular particles, such as are found in the air of ordinary dust-storms."

The most unusual feature, however, was the comparatively large number of diatoms, — varieties of navicula, diatoma epithemia, stauroneis, &c.

For specimens of the substance, and information concerning the

extent of the phenomena, I am indebted to Messrs. J. B. Pence and S. A. Hopple, of Frankfort, the only persons, so far as I have ascertained, who had the forethought to make and preserve collections of the material, or to make immediate inquiry as to the circumstances of its fall in other parts of the county.

A careful microscopical examination, made by Mr. Edwin Bicknell, reveals the presence of the following substances: — Coniferous wood, leaves of mosses, vegetable hairs, scales of butterflies, spicula of fresh-water sponges, and seven genera of fresh-water diatomaceæ. He decides that this "dust-shower" "evidently came from the bed of a bog or boggy brook, as all of the above will be found in such localities."

Hitherto such showers have been observed only in Southern Europe, Northern Africa, and Western and Middle Asia, and the origin of the dust has remained a mystery. In the present instance we are in the dark as to the precise locality from whence the material came, although the microscope indicates to us, *certainly*, the nature of the source, and gives us a clue to the solution of whatever mystery may remain with reference to *this* shower, at least.

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3. The Earthquake of October, 1870. Its Rate of Progress. By Charles Whittlesey, of Cleveland, Ohio.

This earthquake occurred in the forenoon of October 20, 1870. It was distinctly felt from near the mouth of the St. Lawrence to Cincinnati, along a line or axis of about (1000) one thousand miles. The breadth of country along this line, in which the agitation was perceptible, is at its greatest width about 300 miles. Its greatest severity was on the St. Lawrence below Montreal, and its progress was in a south-westerly direction up the valley of this river and of the Lower Lakes. At Quebec, chimneys were thrown down, and a church at Kamarouskoi was so much damaged that one wall and the steeple required to be rebuilt. At Montreal it was severe, and even at St. Catherine, near the west end of Lake Ontario, but decreasing in violence towards the west. At Albany and at Cleveland the extent of the vibrations were about the same, and also

the duration of the movement, which was about a minute. At all other places its duration is reported at less than one minute. It was scarcely felt on the meridian of Lake Michigan. At Albany, according to Professor Hough, a rumbling noise was heard, but at Cleveland there was none. I wish to call the attention of the section to the anomalous rapidity of its progress westward. The time of its occurrence was given by telegraph for *thirty-one places*, but the discrepancies are so great that I use only four. These are Bangor in Maine, Boston, Albany, and Cleveland, Ohio. The errors in time at any of these places must be less than *half a minute*. At Albany, Professor Hough, of the Dudley Observatory, was able to fix it precisely at *fifteen minutes past eleven*, A.M., mean time. According to telegraph reports, it occurred at the same moment at Montreal, which is nearly in the same longitude. At Cleveland, by my watch and by two clocks, which were stopped by the movement, I am able to fix the time within thirty seconds, with a probable plus or minus error of fifteen seconds. It occurred there at *sixteen and one-half* minutes before eleven. The table presented herewith gives, from the best authorities at my command, the local time of its occurrence at the four places selected, as being those best determined.

PLACE.	East of Cleveland in Time.	Time of Occurrence reduced to the Cleveland Meridian. Decimals omitted.	Occurrence by Local Mean Time.	Longitude West of Greenwich.
	h. m. s.	*h. m. s.*	*h. m.*	*h. m. s.*
Bangor, Me. . . .	0.51.41.16	10.43.19	11.35 A.M.	4.35.08
Boston, Mass. . .	0.42.35.16	10.43.25	11.26 „	4.44.13
Albany, N.Y.. . .	0.31.51.10	10.43.09	11.15 „	4.54.58.6
Cleveland, O.. . .		10.43.30	10.43½ „	5.26.49.16

The difference is confined to the column of seconds, where it is only *twenty-one seconds*, or is less than possible errors of observation. Between Cleveland and Bangor, the right-line distance is (650) six hundred and fifty miles; and the difference in time of occurrence is eleven seconds, and from Boston only five seconds.

three hundred and fifty-
one twenty-one seconds;
one miles in a second. Ob-
progress exceeding
which engulfed
in the year
miles a minute from
assume that there is an
and Albany, and place
one second. The velocity
If we make the same
the rate is almost
one minute, or sixty miles in a

[illegible] magnetic needle
which was turned upon-
seven hundred miles
[illegible] in Albany
[illegible] were transmitted
[illegible] moment of time.

[illegible] the Electrical
[illegible] four-and-twenty thou-
[illegible] sand miles in a second
[illegible] of time. It seems
[illegible] to be instantaneous
[illegible] to the senses, as
[illegible] no appreciable
[illegible] portion of time
[illegible] can be measured
[illegible] between the
[illegible] moment when
[illegible] the current
[illegible] leaves one
[illegible] end of the
[illegible] wire and
[illegible] when it
[illegible] reaches the
[illegible] other.

far as Buffalo. On the spot, a crater was formed in the earth and hard pan, said to be fifty feet deep. It probably did not reach the Devonian shales beneath. A vessel, three miles from shore, experienced precisely the same jar or shock from beneath, like that of striking a rock, which persons at sea have frequently reported in severe earthquakes. The rattling of doors and of crockery in many of the lake towns, at the time of the nitro-glycerine explosion, may be due entirely to atmospheric agitation, but the peculiar shock which the vessel experienced must have proceeded from a force acting from below.

This might have resulted from lateral compression disturbing the bottom of the lake. Such action would be transmitted much more rapidly than a surface undulation or earth-wave. I am not able to trace the rate of transmission of the effects of the Fairport explosion, but, at places 150 miles distant, the telegraph reports show no perceptible difference in the time of its arrival.

its long détour northward; and the Cretaceous outcrop doubtless extends, in a north-westerly direction, some distance into Kentucky.

In the portion of this belt embraced within the States of Mississippi and Alabama, the dip is sensibly at right angles to the trend (*i.e.*, between W. and S.) at the rate of twenty to twenty-five feet per mile. In its southerly portion especially, the Cretaceous beds are very distinctly divided into three principal stages, viz.: —

1. A lower one, 300 to 400 feet thick, — *Coffee group* of Safford (Eutaw group *mihi*), — consisting of non-calcareous sands, and blue or reddish laminated clays, with occasional beds of lignite, and but very rarely (Finch's Ferry in Alabama) marine fossils, silicified; corresponds doubtless to Hayden's Dakota group, including, perhaps, in its upper part the equivalents of the Fort Benton group, to whose fossils those of Finch's Ferry, collected by Tuomey, bear a close analogy.

2. The middle or Rotten limestone group, not less than 1,200 feet in maximum thickness. Soft, mostly somewhat clayey, whitish, micro-crystalline limestones and calcareous clays; very uniform on the whole, if we except the locally important, but not generally extant, feature of the "Tombigby Sand," the special home of Inocerami, Selachians, and gigantic Ammonites.

3. Ripley group: crystalline, sandy limestones, alternating with dark-colored glauconitic marls containing finely preserved fossils. Thickness, 300 to 350 feet. Equivalent of the highest bed of the Cretaceous of New Jersey, and doubtless of Hayden's Fox Hills beds.

How far the Rotten limestone, as a whole, may be considered as embracing the whole of the series intervening between Hayden's Fox Hills beds and Dakota group, remains to be shown. The fauna of the Tombigby sand sub-group is distinguished, as already stated, by the great number both of individuals and species of Inocerami, and of remains of (chiefly Selachian) fishes, wherein it corresponds to Hayden's Niobrara division; its fossils have been partly named and described (somewhat imperfectly) by Tuomey.* According to Hayden's view of the New Jersey equivalents, the Rotten limestone would be represented by his Fort Pierre group.

The distinctive features of these several groups become less marked the farther we advance northward, even in Mississippi.

* Proceed. Philad. Acad.

Non-fossiliferous or lignitic clays and sands mingle with the marine strata and become altogether predominant, it would seem, near the northern termination of the outcrop.*

West of the Mississippi the continuous Cretaceous outcrop does not extend as far northward as on the east side, by some 150 miles. Nor have the more ancient lignitiferous beds (Coffee group) been observed there, with certainty, within the limits of this map. The Cretaceous area of Arkansas, according to Owen's description, falls almost altogether within the limits of the Rotten limestone group; and the same seems to be true of the greater part of the Cretaceous area of northern and mid-le Texas. Nevertheless, the series of isolated Cretaceous outliers, which traverses Louisiana from the head of Lake Bistineau in a S.S.E. direction, terminating probably in the great rock-salt mass of Petite Anse,† exhibits the main characteristics of the Ripley group; while deep borings have demonstrated the presence, for a thousand feet beneath, of the uniform Rotten limestone, such as it exists on the prairies of Mississippi and Alabama. I have elsewhere‡ stated the stratigraphical as well as lithological reasons which induce me to consider both the rock-salt of Petite Anse, and the sulphur and gypsum deposits of Calcasieu, as lying within the limits of the Cretaceous formations.

The data given by D. D. Owen seem to assign to the Cretaceous strata of Arkansas a dip S. or slightly W. of S. The outliers in Louisiana are too limited in extent for determinations of dip; but it can scarcely be doubted that they represent the summits of a more or less interrupted ancient ridge, a kind of "backbone" to the State of Louisiana, whose resistance to denudation has measurably influenced the nature and conformation of subsequent deposits. It is fair to presume that from this ridge the strata dip toward the axis of the Mississippi Valley, to meet those on the opposite side; and the depth at which these beds are found in the Calcasieu bores seems to indicate, on the western slope, a south-southwesterly dip of three to four feet per mile. A glance at the map shows, nevertheless, that the general form of the northern Gulf shore was not materially influenced by the existence of this

* Vide Safford.

† Indicated on the map by the localities of Petite Anse, Chicot, Winfield, and Bistineau.

‡ Amer. Journ. Sci., November, 1869, p. 345.

axis of elevation, which probably was marked merely by a series of disconnected islands in the early Tertiary sea that, after the emergence of the immense Cretaceous area, already prefigured the present Gulf of Mexico.

It would be bootless to speculate, at this early moment, on the precise origin of the great rock-salt, gypsum, and sulphur deposits. That the prominent event of the epoch — the emergence of an extensive sea-bottom — afforded abundant opportunity for the accumulation of the two former substances, is obvious enough; it would seem to presuppose, however, a temporary or partial isolation at least from the general ocean, analogous to that which, apparently, occurred in later times. But as regards the sulphur, its ordinary co-occurrence with gypsum would hardly seem to afford a sufficient precedent for the present case; unless we assume the concurrent influence of volcanic or other "abysso-dynamic" agencies.

Tertiary Period.

It will be perceived that, during the Tertiary period, the northern Gulf shore receded from its extreme northern limits in southern Illinois and Missouri, to a shore-line which, though running near the latitude of Bâton Rouge, is not far from parallel to the present one, if we ignore the extreme projection of the Mississippi delta. This rapid filling-in of the embayment, no less than the character of the deposits, prove that the depth of water was not great; especially in the remoter portions, where lignitic and lignito-gypseous deposits very sparingly interspersed with small marine beds (the remnants of estuaries) form the predominant material. Similar alternations of materials occur, in fact, throughout the older Tertiary deposits of the south-west; and hence, the divisions marked off by difference of color on the map, as "lignitic" and "marine" Tertiary, respectively, must be taken very much *cum grano salis*. Except only in southern Arkansas, few marine beds of any notable extent occur outside (*i.e.*, north of) the limit of the area indicated as marine. But in northern Louisiana, where the dip is very slight, lignitiferous strata are altogether predominant on the surface; although the marine seem to underlie everywhere at no great depth, and in numerous localities crop out on the surface; forming, according to Hopkins, distinct beaches around some of the Cretaceous outliers mentioned above.

So far, indeed, from considering the predominantly lignitiferous

such as representing a period distinct from the older marine Tertiary, I have little doubt that the larger portion, if not all, of the beds I have heretofore designated as the Northern Lignitic (and Flatwoods clay) group (Lagrange and Porter's Creek groups of Safford) are the strict equivalents in time of the oldest marine beds observed in South Carolina and Alabama, and designated by Tuomey as the Buhrstone group ("Siliceous Claiborne" of my Mississippi Report). The lithological continuity of the bed-rocks of this group along the eastern border of the Tertiary, supported to some extent by palaeontological evidence, strongly inclined me to this opinion ten years ago;* and it has received a strong confirmation from the latest observations of Dr. E. A. Smith, of the Mississippi Geological Survey, who has found the same rocks substantially continuous along the southern border of the lignitic area, nearly to the Mississippi bluff. At the same time Safford mentions the occurrence of similar beds on the border of the Cretaceous in Tennessee. The inference is inevitable that no beds outcropping in the [illegible] these two marine [illegible] can be [illegible] in time; the interconnection in fact is such as to render the supposition that there can be any material difference of age almost stratigraphically impossible. The exclusively lignitic character of the northern portion must, therefore, be ascribed rather to the inaccessibility of that region to the waters of the sea during that deposition; perhaps in consequence of a change of level, by which the upper portion of the embayment, from about the mouth of the Arkansas to Cairo, was converted for the time being into a littoral marsh.

In Arkansas, nevertheless, small marine beds are more [illegible] interspersed among the lignitic clays than is the case east of the Mississippi; and some of those mentioned by Owen as occurring in the Tertiary east and down to [illegible] lignitic [illegible] were closely related to the [illegible] Claiborne [illegible] the Buhrstone group. The latter group does not [illegible] developed anywhere west of the river [illegible] and the occurrence of somewhat extensive [illegible] Cretaceous territory of Arkansas [illegible] east of Texas (by the [illegible] Timber [illegible] on the map), prove that although [illegible] of the embayment followed substantially the lines [illegible] on the map, yet there still existed at that time a commu-

* Miss. Rep., 1860, §§ 132 and [illegible]

in a north-westerly direction, of the Gulf waters with those of the great interior basin of the West.

That this connection should not be uninterruptedly traceable at the present time is not surprising, when we consider the shallowness of the connecting trough, as demonstrated by the inconsiderable thickness of the deposits, that of course greatly favored their removal by the subsequent events of the Quaternary period. Nevertheless, enough seems to remain of these deposits to form a chain by which, with the aid of paleobotany, the equivalents in time of the Buhrstone and Claiborne marine groups, at least, can be determined among the fresh or brackish water beds of the interior. And with these as fixed horizons to start from, aided also by the flora of the subordinate lignite beds of the later (Jackson and Vicksburg) stages, we may hope to establish a comparative chronological scale through which the parallelisms with more distant regions, and later times, may be established, even for the much-discussed Tertiary beds of the Great West.

My present purpose scarcely requires that I should more than allude to the detail of the later stages of the older Tertiary, which I have not distinguished on the general map, in order not to obscure too much the general features. But a detailed map shows both the successive decrease in the width of their outcrops, and the regularly diminishing convexity of the Gulf-outline. I may also add, that, as we recede from the vertex of the embayment, and eastward from its axis, there is a regular increase of deep-sea features, the lignitic facies becoming more and more subordinate; yet, by its persistent recurrence seeming to intimate the occurrence, if not of oscillations, at least of local variations of depth; dependent, perhaps, upon corresponding changes in river mouths. In Alabama, the lignitic feature is almost suppressed, the marine stages overlying each other directly, as a rule; while west of the Mississippi, it becomes more and more pronounced as we advance westward, so that all but the latest portion of the Jackson, and most of the (much diminished) Vicksburg sea, here represented, appears to have been an intricate maze of everglades and shallow estuaries. That this state of things is intimately connected with the existence of the Cretaceous "backbone" of Louisiana on one hand, and the decided southward dip of the same formation in Alabama on the other, can scarcely be doubted. At the same time, let it be remembered, that both east and west of the Mississippi, from the Chattahoochee to the Sabine, the older Tertiary period closes with a

decided prevalence, in the Vicksburg limestones, of the deep-sea character; and thus far the geological history of the gulf does not exhibit any phenomena whose parallel may not, *mutatis mutandis*, be found on the coast of the Carolinas. Moreover, the transition from the oldest to the more modern (Vicksburg) fauna is so gradual, gaps existing in Alabama and Mississippi being completely filled by transition strata observed by Hopkins and myself in Louisiana, that any attempt at subdivision into eocene and "oligocene," must draw altogether artificial lines of demarcation.

But while on the Atlantic coast we meet, in the Miocene and Pliocene strata of Maryland, Virginia, and the Carolinas, a gradual approximation to, and admixture of, modern marine forms, the Vicksburg epoch closes abruptly, so far as the Gulf of Mexico is concerned, the marine Tertiary series. The geologically as well as agriculturally barren rocks of the *Grand Gulf* age lack all analogy outside of the Gulf basin, unless it be those of the Bad Lands of Nebraska, and especially the White River beds, to which they bear an extraordinary lithological (as well as in some respects, stratigraphical) resemblance. However little this circumstance may prove as regards equivalence in time, we must, nevertheless, not forget that, as the only representative of the geological period intervening between the eocene and the Drift on the Gulf shores, the Grand Gulf group almost necessarily embraces among its equivalents these very beds; and since Marsh has found the latter so much farther south than they were supposed to exist but a short time ago, it is not altogether impossible that more direct relations between the two may yet be proven. The Grand Gulf rocks form the highest ridges of Louisiana as well as of south Mississippi, falling off rather abruptly into the level prairie country of the marine Tertiary. But even these ridges are capped by the ferruginous sandstone of the southern drift, which may have been instrumental not only in greatly diminishing their height, but also in sweeping away the links connecting them with the interior; as has unquestionably happened with regard to the older Tertiary.

Be that as it may, whether actual connection existed or not, we cannot escape the conclusion that analogous circumstances were required to produce analogous deposits. Foremost among these was *the exclusion of the sea;* nor can we account for the extreme scarcity of both animal and vegetable remains, that scarcely leaves us a hope of direct identification, unless upon the supposition that the water which deposited these beds was, take it altogether, too

fresh for a salt-water fauna, yet too salt to admit of a fresh-water population. The solitary fragment of a turtle, recognized by Professor Marsh, is all that has so far rewarded my many years' search for zoögene fossils in this formation; and with the exception of a single locality in Mississippi, not yet fully explored, the prospect for recognizable fossil plants is about equally discouraging.

I confess that such absolute dearth of life rather staggers my belief; and my later observations on the deposits of the Port Hudson (Quaternary) beds have led me to conclude, that in some degree this absence of life is only apparent; and that the *calcareous concretions*, so abundant in some of the clay strata of the formation, are but the substance of perhaps a very diversified fauna, whose calcareous portions have been thus transformed by maceration.* The calcareous ingredient, however, occurs only in the lower, clayey division of the series; and it is sufficiently remarkable that the fine sand and clay stones of the upper division should have preserved no vestiges of either animal or vegetable life.

I do not see how, in view of the nature, thickness (about 250 feet), and wide distribution of this formation, the inference can be avoided, that during the whole or a part of the interval between the Vicksburg and Drift ages, the Mexican Gulf was, by some means, isolated from the Atlantic Ocean; or that at least its communication, perhaps across the still submerged peninsula of Florida, was so imperfect as to render the influx from the interior of the continent predominant over the original supply of sea-water. An upheaval of the northern borders of the Caribbean basin could easily accomplish this result, so long as the deep channels excavated by the Gulf Stream in the Strait of Yucatan, as well as those of Florida, did not yet exist. Too little is as yet known with accuracy regarding the geology of the nearer Antilles and Yucatan, to determine whether they bear the marks of the event recorded by the Grand Gulf rocks on the northern shore of the basin. The observations of Mr. Gabb in Sto. Domingo, and of the Englis geologists in Jamaica, seem to indicate the existence there of marine Miocene and Pliocene tertiaries, which are altogether unrepresented in the waters of the Gulf. It has been suggested to me that beds of that character may be covered by the Grand Gulf, and later beds of the Gulf coast. I willingly leave the onus of proof on that score to those who may think such an assumption desirable.

* Amer. Journ. Sci., January, 1869, p. 81; Ibid., November, 1869, p. 338.

But were this the case, the necessity for assuming the cutting off of the Gulf basin from the Atlantic, on account of the existence of the Grand Gulf rocks, would be none the less cogent; for I doubt whether any geologist, upon full consideration of the facts, would for a moment entertain the idea that, like the "Northern Lignitic" of the older Tertiary, the Grand Gulf beds could be explained away as a mere littoral formation.

It is worthy of remark, that while east of the Mississippi the peculiar sand and clay stones of this group are confined to the northwesterly portion of its area of occurrence, in Louisiana and eastern Texas these rocks are altogether predominant, especially along the northern (or landward) border, the clays being subordinate.

Quaternary Beds.

The Grand Gulf rocks are almost everywhere immediately overlaid by the deposits of the stratified Drift or Orange sand. Of course it overlies equally, as a rule, the more ancient formations (except where, from causes not always readily imagined, it seems to have been subsequently removed) up to the limits of the Palæozoic. Beyond these, its occurrence is more or less localized in conformity with the larger valleys, as observed by Safford in middle and eastern Tennessee, and by Tuomey and myself in Alabama. The same is true, apparently, of the larger channels of Texas. But within the limits of the Mississippi embayment, it constitutes one huge delta-shaped mass, covering the entire Tertiary, and a large portion of the Cretaceous area, to a depth varying from a few feet to over two hundred; on an average, perhaps, between sixty and one hundred feet. Its predominant material is orange or reddish, rounded sand, mostly ferruginous, of various degrees of induration, with subordinate beds of clay, and enormous gravel-streams, evidently denoting ancient channels.* Its beds disappear beneath those of the Port Hudson age about concurrently with those of the Grand Gulf era; and, consequently, it cannot well be independently represented on the map.

I have heretofore† shown that in order to explain the phenomena offered by the Orange Sand of Mississippi and Louisiana, it seems necessary to assume that, prior to its deposition, the Gulf coast suffered an elevation to the extent of at least 450 feet above

* Miss. Rep., 1860, Amer. Journ. Sci., May, 1866, and other papers above referred to.

† Amer. Journ. Sci., November, 1869, p. 385.

its present level, accompanied by a much greater uprising near the head of the waters. This elevation was succeeded, during the "Champlain" epoch, by slow depression to at least twice that amount; and finally, during the Terrace epoch, a re-elevation to at least the extent of 450 feet took place. These figures are *minima*, if we regard the sea, or rather the Gulf level, to have remained constant. But if, as seems necessary to assume, the Gulf was an isolated basin during the Grand Gulf era, it might possibly have been elevated as a whole, and the zero-point of the scale would be changed upward, accordingly. The same, in a reverse direction, would be true if it could be assumed that the occurrence of the glacial epoch sensibly affected the general level of the ocean.

Be that as it may, the gravel is composed of northern rocks, disposed in belts, of which one occupies the main axis of the embayment, while others mark outlets now closed; and the extensive denudation and violent plowing-up of the more ancient formations clearly prove the occurrence of an immense flow of waters southward, which in the main channels moved pebbles of many pounds weight; while between these, the deposition of the finer materials took place in more quiet waters.

That these events were not of a local character; that, on the contrary, the phenomena observed in the Southern States are but the necessary consequence and complement of the Drift phenomena at the North, hardly requires discussion; but it is time that these facts were more generally understood and taken into account by American geologists, and that the Ohio should cease to be proclaimed the southern limit of the "Drift." A kind of settled prejudice on this point seems to have obscured the vision of more than one observer, in consequence whereof these deposits have been claimed, over and again, as portions of every formation existing in the south-west, from the Carboniferous to the Bluff or Loess. Thus, in north-eastern Texas, they have been accounted of Tertiary age; the "Tertiary iron ores" of that region being precisely the same as those of the "Orange Sand" of Louisiana and Mississippi. The same is doubtless true, according to Safford, of the "Iron ore banks" of Tennessee, associated with the "Ore region gravel," precisely as is the case in north-east Mississippi. In Arkansas, Crowley's ridge, a peculiarly characteristic Orange Sand ridge abutting on the Mississippi River at Helena, has been properly accounted of Quaternary age by D. D. Owen; but he associates with it the underlying lignitic beds, which it is impossible to distinguish from those cropping

out directly opposite, on the Mississippi River bluff, in Mississippi and Tennessee; and which are directly traceable to their connection with the oldest Tertiary.

Tuomey first asserted the existence of this southern Drift from Alabama to South Carolina, and conjectured its equivalence to the beds which underlie the cities of Richmond, Washington, and Baltimore. I ascertained its wide prevalence in the States of Mississippi, Louisiana, and Texas, and identified with it the superficial beds observed by Owen in Arkansas and south-western Kentucky, and by Safford in Tennessee. So close and cogent a connection was thus established between it and the "modified Drift" of the North-west, that I can no longer doubt its equivalence, whatever may be the precise mode of origin assigned to it. The "Eastern gravel" streams observed by Safford in the mountains of Tennessee, and no less by Kerr in North Carolina, have their counterparts in the rivers of Texas, and in the great pebble-belts of the Mississippi embayment.

But it will be difficult to combine into a harmonious whole the widely differing observations and opinions of geologists on the vexed Drift question, unless some agreement is come to as to the precise meaning of the word. Let it be understood that the term Drift, *unqualified*, shall embrace all the deposits formed between the end of the Tertiary period and the beginning of the Champlain era of depression, when "drifting" ceased on this continent, outside of river channels, and that within this *Drift period* are embraced, whether as consecutive, or more or less simultaneous, but genetically distinct formations, the Glacier-drift or moraines; the Iceberg (or "glacial") drift of the north-west; and finally the "modified," or rather *stratified* Drift* of the Western, South Atlantic, and Gulf States. It will then become possible, by a comparison of the really cognate phenomena, to trace more definitely the history, both general and local, of that turbulent period, without the confusion attending the use of a word to which each observer attaches, more or less, a different meaning.

If it be fully ascertained that in its lower course the Ohio is (sensibly) the extreme southern limit of the "glacial" Drift, while the stratified Drift is substantially continuous from the lakes to the

* The name, "modified Drift," would be altogether inapplicable to a large part of the southern Drift, which is to a large extent "modified" Cretaceous and Tertiary material, only restratified, Drift-fashion.

Gulf shore, we have before us a definite problem as to the causes, that can probably be solved by a close examination of the critical region; viz., the southern border of the Palæozoic in the Mississippi Valley. The general relations of the Drift to the Alleghany range are thus far, unfortunately, involved in great obscurity; yet a knowledge of these, especially on the western slope, seems almost a necessary condition precedent of any probable hypothesis regarding the history of the Drift period west and south. It is only thus that the possible existence of an ancient barrier across the Mississippi Valley, at the head of the embayment, may be either established or disproved.

The next formation laid down on the map is the Port Hudson group, of which, however, the outcropping *littoral* portion only is here represented. Properly speaking, it should be shown as occupying also most of the space colored as alluvial; since it underlies everywhere, not only the marine alluvium (and a portion of the Gulf itself), but also that of the Mississippi and its chief tributaries, at least as high up as Memphis, and on Red River, nearly if not quite up to Shreveport. It seems to exist equally in the valleys of other larger rivers tributary to the Gulf; notably in that of the Pascagoula, up to one hundred miles (in a direct line) from the coast.*

Having discussed this formation somewhat in detail in papers recently published, I will merely state that it embraces a group of partly littoral and estuarian, partly swamp, lagoon, and fluviatile deposits, whose thickness and location are manifestly dependent upon the topographical features of the continent, then (during the "Champlain" period) in progress of slow depression; as shown by the nature of the deposits, and the numerous superimposed generations of large cypress stumps, imbedded in laminated clays exhibiting the yearly fall of leaves. These beds overlie those of the Orange Sand or Stratified Drift, while they themselves are overlaid by, not only the river alluvium, but also by the Loess or Bluff silt or its equivalents; as well as, where this is absent, by the yellow loam of the surface.

It would seem that here also, during the latter portion of the Drift period, most of the larger river channels were already im-

* See Miss. Rep., 1860, p. 153. The reference of the outcrop at Powe's to the Grand Gulf group is, I think, undoubtedly erroneous; and the same may be true of part or whole of the Dwyer's Ferry section, p. 154.

pressed upon the surface, though not always coincident with the present immediate valley; as Newberry has observed in relation to some of the northern rivers. A depression of the land would gradually transform these channels into inlets filled with more or less stagnant fresh water down to a greater or less distance from the then existing coast line; and thus opportunity would be afforded for the formation of the swamp and lagoon deposits into which both the Mississippi and Red River have subsequently cut their channels. The banks of the Red River as well as, outside the present alluvial area, those of the many lakes and bayous which border that stream, exhibit strata absolutely identical in character with those observed near the coast, yet, of course, totally different from either the alluvial deposits of the present time, or the adjoining tertiaries. The same holds true, more or less, of the Mississippi and its mighty "bayous." According to the observations of Dr. E. A. Smith in the Yazoo bottom, and my own in that of the Tensas, not only do the clays with calcareous concretions (as characteristic of the Port Hudson age as they are foreign to the alluvium of to-day) frequently crop out in the beds of the streams; but much of the best lands of the "buckshot" kind, now situated above overflow, have clearly been formed by simple disintegration of these strata, altogether independently of the river alluvium.

These results fully confirm, therefore, the statement made by General Humphreys,* that the Mississippi does not, as a rule, flow in a bed formed of its own deposits, but has excavated it in an older geological formation. Wells exceeding fifteen or twenty feet ordinarily strike these clays throughout the bottom, as they do in the delta; and the analogy has been completed by the repetition of the phenomena observed in driven wells at New Orleans,† at a point about fifty miles above Vicksburg (General Wade Hampton's plantation), where a tube-well has furnished a copious flow of combustible gas undiminished for many months.

The swamp clays form, however, only the lower portion of the Port Hudson beds. Higher up, as shown at the Port Hudson bluff,‡ there lie yellow or whitish silts and "hard-pans." These form, also, a level terrace some miles in width, bordering the Tensas bottom; while high above it, on the hill-tops of Sicily Island,

* Rep. on the Mississippi River, p. 98, et al.

† Amer. Journ. Sci., vol. i., 1871, p. 345.

‡ See profile in Amer. Journ. Sci., Jan., 1869.

on the Washita, lie the remnants of the Loess formation, the main body of which has succumbed to the erosive influence of the Terrace epoch of elevation. It has, however, left a belt a few miles wide on the eastern side of the valley, as shown on the map.

It would thus seem that during the latter portion of the period of depression, the rate of sinking became, at times, too rapid to allow of the accumulation of swamp deposit. The indurate silts are mostly devoid of fossils of any kind, but are occasionally traversed by fluviatile beds with pebbles, drift-wood, &c. Then there is a recurrence of the swamp deposits; then again silts; and finally, the calcareous, silty loam of the bluff formation, with its numerous terrestrial fossils and "Löss puppets," ends the deposits clearly referable to the epoch of depression.

The Loess differs little from its equivalents farther north, save in being utterly devoid of stratification as well as of any fluviatile organisms. It is not easy to imagine the *modus operandi* by which a deposit of this kind, sometimes seventy feet thick, and of dead uniformity from top to bottom, could be produced. Its equivalents farther north exhibit very distinctly the structure resulting when deposition takes place in (gently) flowing water; at the south it was probably substantially stagnant, save as regards the tidal flow. Perhaps the latter may serve to explain both the absence of fluviatile as well as marine life, and the uniform intermixture, without any semblance of arrangement, of material varying from the finest silt to pebbles half an inch in diameter. A strong tidal wave running up a deep inlet of this kind, would naturally sweep away, in its periodical rushes, many members of the terrestrial fauna, whose remains are in a marked degree the more abundant the nearer we approach to the edge of the formation.

Overlying the Loess we find, wherever opportunity is afforded, a stratum of yellow loam or brick clay, which near the larger valleys is often as much as fifteen to twenty feet in thickness. It is altogether devoid of stratified structure, as well as of fossils, and forms the surface layer, and in most cases the subsoil of the Gulf States. If, as I am inclined to believe, its presence as a connected, though very undulating sheet, on all but the most elevated uplands of these States, necessitates the assumption of submergence, however brief, to the highest level at which it occurs; the changes of level heretofore alluded to would be shown to have exceeded by 600 to 700 feet the estimate given above.

The succeeding (Terrace) epoch of elevation has not, so far as I am aware, left any marks in the way of beach-lines or terraces, unless the second bottoms or "hommocks" be accounted such. They, however, belong to a very modern epoch; for they occur on streams no larger than what is usually called a "creek," and are most marked on the smaller rivers, while apparently absent from those of the largest size, such as the Mississippi, Red, and Arkansas Rivers. The elevation at which, on the very Gulf shore, we find deposits of the Port Hudson age (180 feet at the Five Islands on Vermilion Bay) shows, nevertheless, that a stupendous amount of erosion was accomplished during the time that the Mississippi occupied in scooping out its channel to a depth which, even below the northern boundary of Louisiana, cannot be estimated at less than 500 feet.

As regards the modern epoch, I will merely remark that, while in the axis of the ancient embayment the Mississippi River, through the singular instrumentality of mudlumps upheaval, is rapidly pushing out the land into the Gulf waters, the latter are nevertheless gaining ground on almost the entire coast of Mississippi and Alabama; and the same is true of a portion of Vermilion Bay. Yet, on the whole, the coast of Louisiana, as well as that of Texas and Florida, is more than holding its own; and the shallowness of the water, even where encroachment does take place, will necessarily restrict the latter within narrow limits hereafter.

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2. Western Coal Measures and Indiana Coal. By Professor E. T. Cox, of Indianapolis, Indiana.

The study which I have given to the geology of the West has led me to conclude that the carboniferous rocks embracing the coal-beds, both of the Appalachian and Western coal-fields, were formed in two great depressions that gave rise to large inland seas. These seas communicated with the ocean on the south and west, which then extended far up the Mississippi Valley and covered most of the Southern States, as far north as the thirty-fifth parallel.

A high ridge or plateau of Silurian rocks, capped in places with the Devonian, and lying in a north-easterly direction across the States of Tennessee and Kentucky, and along the western border of Ohio, and the eastern border of Indiana, separated these two seas from each other; and, spreading out over the northern portion of the two latter States, extended into Pennsylvania on the east, and Illinois and Iowa on the west, forming an almost unbroken chain along their northern shores.

In these seas were forming the sub-carboniferous rocks; and, as the water became shallow from the accumulated sedimentary material that went to build them up, a barrier was formed, which shut out the ocean and cut off the source of salt-water supply. Facilitated also by the drainage from a large surface area, the waters of these seas became less and less brackish; and the conditions necessary for the accumulation of the coal vegetation were in this way brought about so gradually, that many marine forms of life continued to exist, and, by degrees, accommodated themselves to the new condition of things.

That marine forms of life are brought to adapt themselves to fresh-water habitudes, under favorable conditions, has been shown by the researches of Dr. William Stimpson, who found, by deep dredgings in Lake Michigan, a species of marine crustacea in great abundance; and similar discoveries had previously been made of marine forms of life by dredging in the large fresh-water lakes of Europe.

From this we may readily infer that the North American lakes communicated at one time with the ocean, and that their fauna and flora were to a certain extent brought to accommodate themselves to the gradual change from salt to fresh water.

The position of the oceans, relative to the land, and the great preponderance of water on the American continent during the carboniferous epoch, must have had a decided influence in modifying the temperature and increasing the humidity of the atmosphere, thereby rendering it in every way adapted to the luxuriant growth of the tropical plants which furnished the carbon so providentially stored away in the fossil fuel; for we find that many of these coal-producing plants, whose dwarfed prototypes are now confined to the tropics, flourished then as far north as the arctic zone.

There could have been no necessity for any increase of carbonic acid or other material change, as some have supposed, in the com-

position of the atmosphere, beyond a slight increase in its humidity; and the probability is that none existed.

The two great coal-fields being separated from each other from the very beginning, as I have endeavored to show, by a barrier of rocks which present no evidence of any subsequent submergence, and which long antedate the carboniferous era, it is difficult to comprehend how any equivalency in the coal-beds of the Appalachian field can be found in those of the west, as many of our eminent geologists have maintained.

It is true that the fluctuations in level which served to build up the various strata may have been, and in all probability were, synchronous over the two basins; but the special requirements for the production of coal-beds could hardly have proved uniform over districts so widely separated.

Though once a firm believer in the equivalency of coal-seams throughout the western coal measures, I have seen much of late to shake my faith in the possibility of determining an entire agreement in the coal-beds, even in the limited area of the coal-field in Indiana.

From a marked irregularity in the thickness of the carboniferous beds over any great extent of territory, we have good reason to believe that these inland seas, like all other great bodies of water, were of unequal depth, and, consequently, did not present at all times over their entire area conditions alike favorable for the formation of coal; and that, while the ocean was excluded from the Appalachian sea, where the material for the coal-beds was forming, the sea on the western side was still filled with salt water, in which was accumulating the sediment that was subsequently changed to rock, and the conditions favorable to the production of coal had not yet been reached. Such a state of things will serve to account for the great discrepancy in the aggregate thickness of the strata in the two coal-fields; the Appalachian being estimated at 2,500 or 3,000 feet, whereas in the western coal-field the greatest depth will hardly exceed 1,000 feet, and in Indiana not more than 700 feet, if so much, though we include in the latter estimate every stratum from the Archimedes limestone upward.

From observations made in the western coal-field during the past three years over portions of southern Illinois, western Kentucky, and Indiana, so many errors have been found in the sections of the coal strata given in the Third Kentucky Report, and which

were pretty generally copied by other geologists in more recent reports, that I have found it necessary to make an entirely new classification of the coals in the West. In speaking of the errors in Dr. D. D. Owen's section of the western coals, I do not want to be understood as referring to the errors of the sections published in his First and Second Reports on the Geology of Kentucky, as some have supposed from reading the remarks on this subject made in my First Report on the Geology of Indiana, 1869, but to the subsequent general section, to be found at pages 18–24 in the 3d vol. "Kentucky Report, 1857," in which some of the most glaring errors of the previously published sections are omitted.

The Kentucky column was the first effort at a general classification of the western coals, and, considering the difficulties encountered in accurately accomplishing so gigantic an undertaking, at a time when a large portion of the country surveyed was almost in the condition of a wilderness and devoid of practical developments from mining operations, it is not at all strange that errors should be found by those who subsequently review the grounds, assisted in their researches by a knowledge of the labors of former explorers, and the still greater advantage derived from more recent developments.

Hence no undue merit is claimed for having been enabled to make more accurate observations than those able geologists who have gone before me; and, with a due conviction that there are many facts yet to learn, from the study of the measures, before a correct general section of the western coal-beds can be given, together with their equivalency over the field to which they belong, I have, in presenting a column of the Indiana coals at this time, omitted the use of numbers, and adopted, provisionally, letters in their place; while gaps are left in the order of succession to be filled by undiscovered seams of coal, or verified by future research.

The following diagram represents three columns of coal, arranged on a common horizon for the purpose of comparison.

No. 1 is copied from "A Geological Reconnoissance of Indiana," by Professor Richard Owen, 1859–60, and represents the order of the coals in Indiana according to Professor Leo Lesquereux. With the exception of some unimportant changes in the lower portion, this column is the exact counterpart, as claimed by its author, of the Kentucky column above referred to.

No. 3.

Connected Section of Coal Measures in Indiana. By Professor E. T. Cox.

Ft.	In.		
45			
4	6	▬▬	Coal *N*.
31	3		
	6	───	Coal *M*.
41			
8		▬▬	Coal *L*.
40			
4		▬▬	Coal *K*.
40			
5		▬▬	Coal *K*.....
17	7		
2		▬▬	Coal *J*.
16			
4	4	▬▬	Coal *I*, Main Blk.
13			
1	6	▬▬	Coal *H*.
17			
4		▬▬	Coal *G*, 2d Block.
23	6		
4		▬▬	Coal *F*, 3d Block.
265	3		"Millstone Grit."
2		▬▬	Coal *B*.
20			
3		▬▬	Coal *A*.
47			Shales and Thin Coal.
659	5	Total.	

No. 2.

General Section of Coal Measures in Southern Illinois and Western Kentucky. By Professor E. T. Cox.

Ft.	In.		
118			"Anvil Rock."
3		▬▬	Shale and Thin Coal.
36	8		
2		▬▬	Coal No. 8.
46			
5		▬▬	Coal No. 7.....
41			
2	6	▬▬	Coal No. 6.
65			
5		▬▬	Coal No. 5.
86			
2	6	▬▬	Coal No. 4.
90			
3		▬▬	Coal No. 3.
24			
4		▬▬	Coal No. 2.
140	6		
1	8	▬▬	Coal No. 1.
130			"Millstone Grit."
	3	───	Thin Coal.
65			
	8	───	Coal.
165			
1036	9	Total.	

No. 1.

Connected Section of Coal Measures in Indiana. By Professor Leo Lesquereux.

Ft.	In.		
50			
	8	▬▬	Coal No. 1 *B*. "Carthage Limestone."
58			
2	8	▬▬	Coal No. 17.
35	8		
	8	▬▬	Coal No. 16.
82	9		
2	6	▬▬	Coal No. 15.
115	4		
1		▬▬	Coal No. 14.
78	6		
	4	▬▬	Coal No. 13.
100	2		"Anvil Rock."
	3	▬▬	Coal No. 12.
20	9		
5		▬▬	Coal No. 11.....
45	10		
3		▬▬	Coal No. 10.
67			
5		▬▬	Coal No. 9.
49			
2	6	▬▬	Coal No. 8.
43			
2		▬▬	Coal No. 7.
84			
3		▬▬	Coal No 6.
65			
4		▬▬	Coal No. 5.
119			"Mahoning."
4		▬▬	Coal No. 4.
34			
4		▬▬	Coal No. 3.
103			
3		▬▬	Coal No. 2.
62			
4		▬▬	Coal No. 1 *C*.
53			
5		▬▬	Coal No. 1 *B*.
32			
2		▬▬	Coal No. 1 *A*.
60			"Millstone Grit."
3		▬▬	Subconglomerate Coal.
			Archimedes Limestone.
1415	7	Total.	

No. 2 presents a column of the Kentucky coals, as corrected by myself, and —

No. 3, a corrected column of the Indiana coals.

Column No. 3 is established upon the best evidence now before me; and though in some of its parts there may prove to be errors, still, as a guide in conducting researches for coal-beds, it is confidently believed that it presents the best solution of the Indiana coal strata yet given to the public, and that, in the main, it will be sustained by future investigations. In prosecuting the survey of Indiana, my assistants are requested not to force local sections to agree with this column, but rather give the order of the strata just as they are found, and leave equivalencies, unless clearly proved, to a final summing-up of all the evidence collected.

In the connected section of the western coal-beds, given at pages 18–24, 3d vol. Kentucky Report, the measures are divided into upper and lower coal measures; and this arrangement, with some local modifications, has, until recently, been generally adopted by geologists.

Now, so far as my observations go, either in Kentucky, Illinois, or Indiana, I can find neither lithological nor palæontological evidence which can be relied upon for cutting up the western coal measures into separate epochs. The "Anvil Rock" sandstone, which was brought into requisition for this purpose, can hardly be depended upon as a horizon, beyond the small district in which it was first discovered; and the equivalency of the Mahoning sandstone of the Pennsylvania geologists, as designated by Owen and Lesquereux, has also proved totally unreliable as a basis for division, even though it should be found necessary to establish one. In the 3d vol. Kentucky Report, and in the "Report of a Geological Reconnoissance of Indiana," 1859, the latter stone is at one place referred to the horizon of the "Anvil Rock" sandstone, and at another locality to that of the "Millstone grit." Indeed, so unfortunate has been the effort to transplant the "Mahoning" sandstone, of Pennsylvania, into our western coal measures, that I can recall no prominent locality where it is not distinctly referable to one or the other of the above sandstones. For the equivalency of sandstones in the western coal-field, I have, as yet, been unable to find any lithological or palæontological evidence which can be relied upon as a guide to identity.

In the Indiana Report by Professor Richard Owen, 1859–60, Professor Lesquereux refers, from palæontological evidence, the

sandstone above the "Knob" coal in Spencer County to the "Mahoning" sandstone, and appears undecided whether the position of the "Martha Washington" sandstone, which forms the bluff at Rockport, and presents a vertical face of thirty to fifty feet on the side fronting the river, should be referred to the "Mahoning" or to the sandstone above coal No. 2 of his general section, given at pages 299–305 (column No. 1 of diagram). At these localities, from my own examinations, I find the Rockport sandstone to be the "Millstone" grit, and the "Knob" coal to be coal *L* of my general section of the coals in Clay County, column No. 3 of the diagram. Consequently the sandstone which overlies it in the hill, if referred at all to an equivalency in the Kentucky section, will be at least about the place of the "Anvil Rock" sandstone.

At Washington, in Daviess County, Professor Lesquereux found a paucity of palæontological evidence; nevertheless it was believed to be sufficient to warrant him in referring the main coal of that place to No. 1 *B* of his section.

In his account of the measures in Daviess County, no mention is made of the heavy bed of sandstone two miles north-east of Washington, which is overlaid by the "Washington" coal, which he refers to No. 1 *B;* this sandstone is quite a marked feature in the geology of this part of Daviess County, and is underlaid by two workable beds of coal, — the upper three feet thick, and the lower three to six feet thick; the space between the two varying from twenty to forty feet. The lower coal has, usually, a limestone over it, and being the second coal in the descending order below the "Washington" coal, is represented as *K* in my section. A coal fourteen miles north of Washington, overlaid by limestone, is, from its position, referred by him to coal No. 1 *C*. I suppose the coal in the bed of the river below Edwardsport, in Knox County, is the seam here referred to; if so it is the second seam below the "Washington" coal. Now the "Washington" coal is at least as high up in the measures as coal *L* of my section. The first coal below it in Daviess County was not recognized in Clay County; and, at the time of making my section, it was thought that no coal would be found intervening between *L* and *K:* consequently, I am now compelled to make an interpolation of a letter, and designate this coal, provisionally, as *X;* the coal with the limestone above it as *K;* and the five-foot coal-bed near the top of the hill at Edwardsport, which is the equivalent of the "Washington" coal, as *L*.

Passing on northward into Clay County, coal *I* of my section refers to No. 1 *A*, and *K* to No. 1 *C*, of Lesquereux' section.

Now, it is clearly demonstrated, in this county, that there are two workable block-coal beds in a space of fifty to sixty feet below the seam reported by Professor Lesquereux as No. 1 *A*, or the lowest workable seam.

At Garlick and Collins' mine on Otter creek, in Clay County, *K* is seen in the side of the hill in the road-cut; *I* is worked by a drift; and *G* is worked by a shaft sunk at the foot of the hill, on the bank of the creek.

Both *I* and *G* are here loaded into the cars from the same coal-tip.

In my first Report, 1869, I pointed out the existence of a second workable seam of block coal below the seam then generally worked: its position in the column was determined from imperfect outcrops; and, for a time, an error was committed in confounding it with a still lower seam, *F*.

Previous to my survey of Clay County, no geologist or any other person who examined the grounds ever dreamt of finding another workable bed of coal below what was called the Brazil seam, *I*. They universally believed that the strata at Brazil indicated the latter seam to be the lowest workable coal in the coal measures proper, and, consequently, that no lower seam of any economical value could be found below it. Since publishing my first Report, the second seam has been reached by shafts, and worked at a number of localities in the county, and the existence of the third seam is fully proved by bores.

At Highland, two miles west of Brazil, *L* of my column is the principal coal worked, and probably the only seam in the basin, at that locality, which is of a suitable thickness to be mined with profit. Notwithstanding the high position which it undoubtedly occupies in the measures, we find that it is referred by Professor Lesquereux to No. 4 of his column; the same seam, at Williams, to No. 3; and the sandstone which is seen above the coal at Highland he refers, without doubt, to the "Mahoning" sandstone. In fact, the misplacing of coal-seams, and the confounding of sandstones at all levels with the "Mahoning" sandstone of Pennsylvania, and the "Anvil Rock" sandstone of Kentucky, I might continue to trace throughout the entire coal-field of Kentucky, Indiana, and Illinois.

In the Kentucky Reports, and "The Report of a Geological Reconnoissance of Indiana," as well as in the reports of other geol-

ogists who have written on the western coal measures, the distinguished authors appear to have satisfied themselves that the western coal-beds and sandstones are synchronous with the Appalachian strata; and that the "Mahoning" sandstone, there a conspicuous horizon, must, as a matter of necessity, have a similar place in the western field, and divide here, as there, the measures into upper and lower coal measures; and that the coal-beds should conform thereto.

Having pointed out a few of the errors committed in the stratography of the Indiana coals, at localities where their position can be proved beyond a doubt, I will now proceed to show some of the errors that exist in the Kentucky column, from observations made at the same localities that furnished the data upon which it was constructed, and which column served as a basis for the arrangement of the coal-beds and sandstones of all other districts in the West.

The column of the coal measures of Kentucky, given at pages 18–24, 3d vol. "Geology of Kentucky," presents us with 1,350 feet of strata above the "Millstone" grit, or Caseyville conglomerate.

From the sandstone under coal No. 18, down to the "Anvil Rock" sandstone, there is a repetition of the strata, including the latter rock, probably as far down as No. 7. This part of the column was constructed from bores that started on the Carthage limestone, which in Union County, Kentucky, is, I now believe, the equivalent of the limestone over coal No. 11. Though the details of strata passed through in these bores can hardly be relied upon, and in no two instances do they fully agree as to the character of the rocks, still the place of the coals, and probably their full thickness, is given with considerable accuracy, as the parties who made the bores were in search of that mineral. Therefore, in the arrangement of this part of the column, it was erroneously assumed that the bottom of the lowest bore in Union County, starting from the horizon of the Carthage limestone, stopped just before reaching coal No. 11. From No. 17 down to No. 13, by reference to column No. 3 of the diagram, you will observe the close agreement in the spaces between the coals above and those below No. 11. In the former they are 35, 102, 115, and 77 feet respectively, while in the latter they are 46, 67, 86, and 127 feet; the aggregate distance from No. 17 to No. 13 being 329 feet, and from No. 11 to No. 6, 326 feet. In giving the space from No. 8 to No. 6, I have

omitted No. 7, which at best is but a streak of coal, and has no existence in Union County, where the principal data for the section was obtained. We are thus carried down to about the place of the "little coal" at Mulford's, now Shotwell's mine, or No. 6 of the Kentucky column. From No. 5, passing down, there is but one thin coal seam in the space intervening between it and "Bell's" coal, or No. 1 *B*.

The "Curlew" sandstone that is referred to a horizon just below the "Mahoning" sandstone, of Pennsylvania, is the equivalent of the "Anvil Rock" sandstone; No. 4 is No. 11, and No. 3 is the equivalent of No. 1 *B*, or "Bell's" coal, which lies just above the "Millstone" grit or Caseyville conglomerate. In Union County, Kentucky, there is a thin coal in the conglomerate below "Bell's" coal, but there appears to be no workable seam.

The total thickness of the strata in the Kentucky column, exclusive of the "Millstone" grit, is 1,350 feet; now strip it of the above errors of repeated strata, and we have as the depth of the carboniferous rocks in Union County, Kentucky, only 612 feet, including the "Millstone" grit.

The above errors are in a great measure to be attributed to too great a reliance on palæontological evidence, and to an apparent desire to make the measures conform to the Pennsylvania sections of the Appalachian coal-field. Though there are some striking analogies, so far as relates to the character and peculiar arrangement of their accompanying rocks, which were first pointed out by myself in a lecture on the western coals in 1857, between the Pittsburg seam of Pennsylvania and the mammoth seam of the western measures (No. 11 of Owen's, and which may prove to be *K* of my column), yet, from the undoubted disconnection of the two fields while the coals were being formed, it is difficult to conceive how any reliable equivalency can be established.

More especially are we led to doubt the equivalency if we take into account the great preponderance of coal-measure strata in the Pennsylvania district, which goes to show that the conditions necessary for the production of coal extended over a much greater period of time in the Appalachian than in the western field.

Though I have assumed that the greatest depth of coal strata in the western measures will not exceed 1,000 feet, in Indiana it will not be found greater than 650 feet, including the "Millstone" grit. In a few localities in this State there are one or more very thin seams of coal below the Archimedes limestone, but no coal of any

economical value has yet been found lower than the base of the "Millstone" grit.

There are, in Indiana, two well-defined zones of coal, the eastern and the western zone, and though an equivalency in some of the seams is clearly traced from one to the other, yet the quality of the coal is quite distinct in each.

The eastern zone extends from the Ohio River, in Perry County, on the south, to Warren County on the north, being about 150 miles in length, with an average width of three miles. The outline of the eastern boundary has a north-westerly and south-easterly trend, but is very irregular, and marked by numerous tongue-shaped projections, which have been, here and there, cut across by denuding forces, leaving patches, or outliers, of carboniferous rocks, with their seams of coal resting on the sub-carboniferous limestone far beyond the true boundary of the coal measures.

The area of the eastern zone is about 450 square miles, or 288,000 acres, and the included coals belong to the bituminous variety characterized as *non-caking* or *free-burning*. The "*cherry-coal*" or soft coal of England is a non-caking coal; but the non-caking coals of Indiana differ somewhat in physical structure from the English coal, and a similar class of coals found in the Mahoning Valley, Ohio, and the Shenango Valley, Pennsylvania; the two latter being the only other localities in the United States where non-caking coal is found in any quantity. The Indiana coal from this zone has received the local name of *block coal*, a name given to it by the miners on account of the facility with which it can be mined in blocks as large as it is possible to handle. The beds are crossed nearly at right angles by joint seams that greatly facilitate the operation of mining, which is usually carried on without resort to blasting. Blocks are taken out smooth the full depth of the seam, and leave a zig-zag notched outline on the face of the mine resembling a Virginia worm-fence.

Block coal has a laminated structure, and is composed of alternate thin layers of vitreous dull black coal and fibrous mineral charcoal. In the direction of the bedding lines it splits readily into thin sheets like a slate, but breaks with difficulty in the opposite direction. When struck with a hammer, it emits a sound like that given by wood. Chemically it does not appear to differ from the caking coals, but in burning behaves quite differently. Unlike the latter it does not swell, shoot out jets of gas, nor form a cake by running together; neither does it leave an ash mixed with

clinker, but retains its shape like hickory wood, until entirely consumed to a small quantity of white ash, which contains no trace of clinker. I have not yet had time to make an ultimate analysis of the block coal; but I believe that when so examined its superior heating properties, which have been determined in practice by actual work done, though mainly due to its physical structure, will be found in part owing to its containing less oxygen, and relatively more hydrogen, than is commonly found in bituminous coals. The block coal, in the great majority of the mines that have been opened, is remarkably free from sulphur and phosphorus. A specimen taken from Garlick and Collins' new shaft, coal *G* of my section of Clay County, and which has a specific gravity of 1.232, gave in 100 parts:—Water, 2.10; gas, 37.35; fixed carbon, 57.95; ash, white, 2.60; and contained sulphur, 0.070; phosphorus, 0.22.

At the White River Valley Rolling Mill, in this city, I was informed by the superintendent, Mr. Sims, an experienced iron-master from Pittsburg, that it not only required a less quantity of block coal than of any of the coals in use around Pittsburg to make a ton of wrought iron, but that they were likewise enabled to bring off the heats in a much shorter space of time, and the resulting iron is of a superior quality, — three important advantages that cannot be overlooked by iron-masters. And it must be conceded that the good behavior of a coal in the puddling furnace is one of the very best tests of purity and effective heating properties to which it can be subjected; for here its good qualities are brought into requisition, and the bad ones are soon made manifest in the poor quality of the iron produced.

Though the blast furnaces of Clay County cannot be looked upon as filling all the requisites of an iron furnace best adapted to the use of block coal, still they are enabled to make a ton of No. 1 foundry iron that will in quality compare favorably with charcoal iron, by the use of less than two tons of coal. And I feel fully satisfied that by materially increasing the width of these furnaces across the boshes, and raising the temperature of the blast to 1,200°–1,500°, that the make will be greatly increased and the consumption of coal very much reduced. By increasing the cubic contents of the furnaces, and raising the temperature of the blast, they have been enabled in the Cleveland district, England, to lessen the quantity of coke fully one-fifth per ton of iron made.

In the block-coal zone of the Indiana coal-field, there are as many as eight seams of non-caking coal, four of which are of good

workable thickness over a portion of the field. There are *I*, *G*, *F*, and *A*, which together have a maximum thickness of fifteen feet, and by including the other four seams we have six feet more, making a total of twenty-one feet of block coal. If we take one-half of this as a moderate average over the 288,000 acres comprised within the eastern zone, it will give us 5,269,017,600 tons of coal, adapted to the smelting of iron, which will produce, at the rate of $2.25 per ton — the average price of this coal at Brazil — the sum of $11,855,289,600.

Ample allowance is here made for loss of coal incurred in mining, and the estimated value is believed to be within bounds. The superior excellence of the block coal for smelting and working iron and steel, in all the varied departments of their manufacture, has been fully established by practical tests. Pig-iron made with this coal is in every respect equal to charcoal iron made from the same ore; it is a soft gray iron, of highly crystalline structure, contains a large percentage of combined carbon, with but a mere trace of sulphur and phosphorus, — properties which render it admirably adapted to the manufacture of Bessemer steel.

For steam and household purposes, it has likewise an unrivalled reputation. It burns under boilers with a full and uniform flame, that spreads evenly over the exposed surface, thus securing a more uniform expansion of the boiler-plates, and greater freedom from leaks, that are so common when caking coals are used. No clinkers are formed; and owing to its freedom from sulphur it has but little detrimental effect upon the boilers, grates, or fire-boxes. I am informed by the owner, Mr. Stunkard, that a boiler in a saw-mill at Brazil, under which block coal is burnt, has been in use for sixteen years without requiring any repairs, and is now in good condition.

Mr. Charles R. Peddle, late general superintendent of the St. L. V. T. H. & I. R. R., informed me by letter that this company have been using the block coal from Clay County for the past two years on locomotives with excellent results. He says:—

"The coal is free-burning, does not cake in the fire-box, makes no clinkers, burns completely to ash, and requires very little more attention in firing than wood.

"Its freedom from sulphur renders it completely harmless to the iron of the furnace and flues; and the only difference between it and wood is that the heat is concentrated upon the lower sheets of the fire-box instead of being more generally diffused as in wood, and greater care must be taken

in keeping the legs of the fire-box clear of scale and mud. We are running our western division of passenger engines from Terre Haute to St. Louis, 165 miles, with one tender of coal, averaging three tons (of 2,000 pounds each) per trip. On the eastern division (Terre Haute to Indianapolis), it is used on freight engines only, and the average number of miles run to one ton of coal, in the year 1870, was 26.28, and the cost per 100 miles was $9.51, which includes cost of hauling, and cost of wood for kindling fires. This statement does not, of course, show as favorable results as would be obtained if the coal was used on both passenger and freight engines, as the latter requires as much as fifty per cent. more fuel, per mile run, than the former."

This coal has recently been introduced on many other roads, on all of which it has given perfect satisfaction.

The block coal does not require as much draught as caking coal; consequently, an engine may be run with it that is constructed for burning wood. But to obtain the best results on engines designed to burn block coal, they should be so constructed as to secure the proper draught, as all in excess of this will cause a waste of fuel. This rule holds good also with regard to burning the block coal in grates or heating stoves; *i.e.*, the draught should not be as strong as is required for burning caking coals. Block coal burns in grates with a bright, cheerful blaze, like hickory wood; makes a very hot fire, and for comfort and economy, when properly burnt, surpasses any other bituminous coal with which I am acquainted. It is used at the Indianapolis Glass Works; and Mr. Fought, one of the company, informed me that the glass-pots, which cost from $100.00 to $125.00 each, and last from six to eight weeks when fired with Pittsburg coal, will last at least *two weeks* longer when block coal is used.

The western zone of coals in Indiana comprises by far the greatest area of measures, being somewhat over 6,000 square miles, and contains three or more very thick beds of coal, besides a number that are too thin for working. Its eastern boundary, which is formed by the zone of block coal, is irregular in outline; and, with my present knowledge of the geology of the country, it cannot be well defined. It is evident, however, that the block-coal beds, as we go west, are changed in character, and pass into caking coal. The lower members thin out, and are no longer of workable thickness, even before reaching the Wabash River. Of this we have abundant proof, by the three deep bores made at Terre Haute. These bores commenced about forty feet above low water of the

Wabash River, and, after passing a few feet of alluvium deposit, were in strata of gravel, sand, and hard-pan, peculiar to the drift epoch, for a depth of about 150 feet; and, though they penetrated the Silurian rocks, the records show that but five seams were passed, only the top one being of workable thickness, while the lowest is but 293¾ feet below the surface.

Two and a half miles east of Terre Haute, coal *N*, which is worked by a shaft at Seelyville, crops out; this indicates a rise of the strata to the west; and, as a still further means of accounting for the absence of the upper part of the coal measures in these bores, it is possible that the great bed of drift, which is found on the east bank of the Wabash at Terre Haute, filled up a ravine or valley from which some of the upper coal-beds were removed by abrading forces.

On the west bank of the Wabash River, coal *L* is mined in a number of places from shafts thirty to fifty feet deep.

From the foregoing data, therefore, I am enabled to correct the error into which I fell in my first Report, 1869, of making the top coal, in the Terre Haute bore, coal *L*, and now place it, at least, as low down as coal *I*.

Though from the records of these bores it is difficult to point out the base of the coal measures, or that of the "Millstone" grit, with any degree of accuracy, it is, nevertheless, my opinion, that the latter epoch commenced at about the depth of 500 feet.

This thinning out of the coal-seams, as we go west toward the centre of the basin, is a remarkable feature, first pointed out by myself in 1867.

A few miles west of the Indiana line, in Clark County, Illinois, bores have been made, in searching for petroleum, to the depth of 800 feet without passing a single workable seam of coal; and the two or three thin seams, reported in some of these bores, are in the upper part of the measures.

Judged by the dip of the coal on both sides of the river, the Wabash runs on a slight anticlinal axis; and I believe this to be the case from Attica, in Fountain County, to its mouth in Posey County, and that, along its course, it cuts through the same strata of rocks from the bluffs at Merom to its confluence with the Ohio River.

Near the eastern boundary of the zone of caking coals, in Indiana, we find *K* and *L*, and sometimes *N*, of good workable thickness, averaging from four to eight feet; and at one locality in Pike

County, there is a bed, not yet studied, but thought to be *K*, that attains to the thickness of ten feet or more.

Taken all together, the maximum thickness of these beds may be estimated at twenty feet, and will yield an average, over the greater part of the district, of ten feet of coal. At some localities the caking coal is of inferior quality, and largely contaminated with pyrites, which is so generally disseminated through the seam that it is impracticable, in mining, to entirely separate it from the coal. In many of the counties, however, within this zone, the caking coals will compare very favorably with the caking coals of the Pittsburg district.

Coal *L*, at Washington in Daviess County, is a bright, rich-looking coal, very free from sulphur; is extensively mined, and meets with a ready market at St. Louis, and all the towns along the O. & M. Railroad. I am informed that this coal is used by the gas companies of St. Louis and Vincennes, and that, both as to yield and illuminating quality of the gas produced, it holds an average rank with the gas coals that have been tried at these places.

The specific gravity of this coal is 1.294; a cubic foot weighs 80.87 pounds, and by analysis it yields: fixed carbon, 60.00; ash, 4.50; volatile matter, 35.50. The coke is bright, porous, and slightly laminated.

The percentage of coke, in the caking coals of Indiana, ranges from 52.00 to 64.50, and the ash from 0.50 to 7.00 per cent.

In Perry, Spencer, Warrick, Vanderburg, Gibson, Pike, Daviess, Sullivan, Greene, Clay, Vigo, Parke, Vermillion, and Fountain Counties, there are seams of rich-looking and pure caking coal, which have, for the most part, been but recently developed by the survey; and I feel assured in saying that they will prove to be good gas coals when subjected to a practical test on a large scale.

The chemical analysis of a coal is not always a safe guide for determining its value for gas purposes.

From her geographical position, and more especially on account of the extent and value of her coal-beds, and the peculiar adaptation of this coal to the metallurgy of iron and steel, which now forms one of the leading industries of the world, we can safely predict for Indiana a bright future as a manufacturing State. The commerce of the new *far west*, which is increasing with a rapidity unprecedented in the growth of empires, will just as naturally look to Indiana for its supply of iron and steel, with which to keep up

the system of railroads traversing the great plains to the Pacific Ocean, as the old west formerly looked to Pennsylvania.

In Indiana we find the last great belt of timber suited for manufacturing purposes; and after crossing her border, thence to the Pacific Ocean, no coal has yet been found that can successfully be used in the manufacture of iron.

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3. Remarks on the Geology of the Mississippi Bottom. By Eugene A. Smith, of Tuscaloosa, Alabama.

It has generally been assumed that the formation underlying the Mississippi bottom was exclusively of alluvial character (see Lyell's "Principles of Geology," tenth edit., ch. xix., vol. i.).

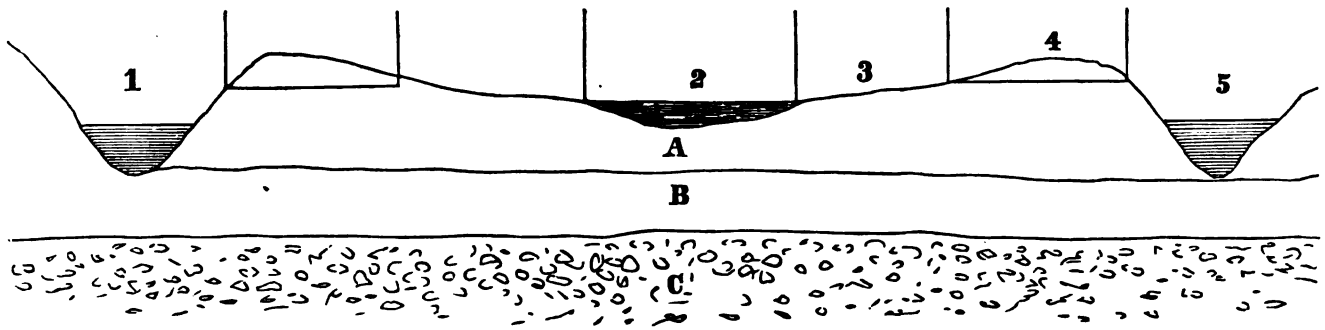
On the other hand, it has been suggested by General Humphreys ("Report on the Mississippi River," p. 99) "that the river is flowing through it (the delta region) in a channel belonging to a geological epoch antecedent to the present." On p. 84: "From McNutt to Sunflower River, underlying the vegetable mould and alluvion, is a stratum of dark, heavy clay, which, when exposed, is called 'buckshot' land by the settlers, from its fancied resemblance to leaden balls when it has been baked and cracked by the sun."

Dr. Hilgard remarks ("American Journal of Science," January, 1869): "The stump stratum No. 1 (Port Hudson profile), however, as appears from numerous data collected by myself, or contained in Humphreys and Abbot's Report, exists at about the same level (*i.e.*, near that of tide-water); not only over all the so-called delta plain of the Mississippi, but also higher up, perhaps as far as Memphis."

Observations made by myself in the Yazoo bottom, during the last year, lead to the conclusion that the true river deposits, of any considerable thickness, are mostly confined to narrow strips of land, lying on both sides of the Mississippi, and of the bayous and creeks,—that form a network of streams throughout the bottom,—and to ancient channels since filled up; while a large proportion

THIS DIAGRAM OF A SECTION THROUGH TWO BAYOUS, AND THE LAND INTERVENING BETWEEN THEM, WILL GIVE A FAIR IDEA OF THE GENERAL TOPOGRAPHY OF THE BOTTOM.

SECTION IN MISSISSIPPI BOTTOM, SHOWING THE ARRANGEMENT OF DEPOSITS.



1. Bayou.
2. Cypress Swamp.
3. Middle or Back land.
4. High or Front land.
5. Bayou.

A. Port Hudson Clays.
B. Blue Clay, with sticks and logs.
C. Gravel of Orange Sand age.
Between A. and 2, Buckshot.

of the superficial area of the bottom, including some of the most fertile lands, is derived from the clays of older formations into which the beds of these streams have been excavated.

The high, or "front-land," on the immediate banks of the streams, is at present rarely overflowed. It is usually a sandy loam of various colors, and of various degrees of fertility. It supports a growth of sweet-gum, honey-locust, swamp-chestnut, oak, water-oak, dogwood, hackberry, pecan, and cane. The growth varies with the locality and character of the loam, as may better be seen below in the remarks preceding the analyses.

These high lands seem to represent the true river alluvium.

From the "front-land" there is a gradual slope down towards the swamp. The soil undergoes a transition from the sandy loam into the tenacious clays of the middle or "back-land." The latter is often overflowed during the wet season; and it supports a growth of sweet-gum, over-cup-oak, willow, and water-oak, hackberry, pecan, and cane.

The clays of the "back-land" doubtless belong, for the greater part, to the Port Hudson age, as is indicated by the abundance of ferruginous and calcareous concretions found in them, unlike any found in the true river alluvium, as well as by the great thickness of continuous clay deposits.

These clays are generally of a dark gray color, sometimes nearly black; again, light gray, traversed by cracks, and full of streaks and dots of ferruginous matter.

They are very sticky and tenacious, and, when exposed in large masses to the atmosphere, become covered on the surface with a dull red coating of hydrated ferric oxide. When broken up by the plough or spade, they crumble on drying into small angular lumps, of the size of a buckshot and under, giving rise to what is known throughout the bottom as "buckshot soil."

Although these clays, as shown by analysis, are generally very rich in lime, yet calcareous concretions, so characteristic of the Port Hudson strata, are not always to be found in them.

Thus, I have not observed them further south than the latitude of Yazoo City. North of that point, however, they are of constant occurrence.

The uniformity of level in the bottom may very well account for the failure to observe these concretions, for any thing like a fair profile is very rarely seen. The banks of the creeks and bayous are usually of such a gentle slope, and so covered with detritus in

their lower parts, that little of interest can be observed without much digging.

As we go from the "back-land" to the cypress swamp, there is frequently very little change in the nature of the clay; and it is difficult, if not impossible, to distinguish between the "buckshot" clay of the older formation and that of the recent swamp, except where the calcareous concretions above mentioned come to our aid. The clays of both formations are usually dark gray, traversed with cracks, and full of ferruginous matter; both crumble into "buckshot;" both support a similar vegetation, except where the presence of more or less standing water affects it.

As the swamp is under water for a large part of each year, there is one alternation in its deposits between clay, leaves, and sand.

One of the most characteristic sections of Port Hudson strata, observed, is on the bank of Tchula Lake, at the head of Honey Island. The three uppermost strata represent the alluvium, while those below are of the true Port Hudson character.

On the banks of the Yazoo River, not far from where the above section was taken, the succession of the strata was essentially the same; but the "buckshot" clays, corresponding with Nos. 4 and 6 supra, were entirely full of calcareous concretions, while the ferruginous concretions occurred at a lower level, nearly down to the water's edge, as is the case at Port Hudson.

On Lake Beulah, in Bolivar County, the same strata appear; the clays, Nos. 4 and 6, being full of calcareous concretions. On Panther Creek, above Yazoo City, and on a small bayou which empties into the river at the city, the same facts may be observed.

Of the stump stratum, No. 1 of Dr. Hilgard's profile, I have not seen any outcrop on the banks of bayous, &c., on account of the difficulties mentioned above. Logs, however, have frequently been struck in digging wells; though the introduction of tube or driven wells has very much impaired this source of information regarding the strata in the bottom.

For instance, on General Wade Hampton's Walnut Grove Plantation, near Lake Washington, at a depth of about thirty feet in the blue clay which underlies the dark gray "buckshot" clay, a fragment of wood was found.

On the same plantation, while driving a tube for the purpose of obtaining water, a stream of inflammable gas was observed to issue from the tube. At the time of my visit there, the gas had

SECTION OF ALLUVIUM AND PORT HUDSON STRATA, BANK OF TCHULA LAKE, AT THE HEAD OF HONEY ISLAND.

	Feet.		No.
ALLUVIUM.	3	Top sandy clay with yellowish dots, similar to No. 8 of the soils mentioned below.	9
	4	Grayish, mottled, massy, "joint" clay, with ferruginous coloring matter in spots.	8
	4	Lighter colored and sandier stratum, with yellow ferruginous streaks.	7
PORT HUDSON.	6	Dark gray stiff clay, with ferruginous streaks, crumbling on exposed surface to "buckshot."	6
	Inch. 4	Gray sand, tinged yellow, in places, with hydrated oxide of iron.	5
	Feet. 2	Dark gray stiff clay, like No. 6.	4
	2	Gray sand, slightly tinged with iron above, but full of ferruginous concretions (tubes and plates) in its lower parts.	3
	2½	Ledge of blue clay, with ferruginous concretions interstratified with streaks of bluish sand, the stratification lines being strongly ferruginous. Exposed surface covered with white efflorescence.	2
		Talus to water's edge; numerous little springs which make a copious deposit of hydrated ferric oxide issue from this stratum.	1

been burning uninterruptedly for three months. It escapes with considerable force, and might easily be utilized on the plantation.

The composition of this gas is as follows:—

CH_4	= 74.30
N	= 19.00
H	= 8.20
CO_2	= 8.50
	100.00

The small percentage of carbonic acid found in this gas shows that it does not originate from vegetable matter in its first stages of decomposition, agreeing in this respect with the gas obtained from similar wells in New Orleans,* and differing from the gas of recent marshes, which contains from 8 to 10 per cent.

Below the stratum of blue clay, in which sticks, logs, &c., are found, there is a stratum of pebbles and sand, of the Orange Sand formation. This pebble bed is very often reached in digging wells.

The depth varies very greatly: thus, at the mouth of a small bayou, which empties into Lake Washington on the west side, there is a bed of pebbles at low-water mark, as is also the case at Proffit's Island,† near Port Hudson; while in some wells it is not reached at a depth of 120 feet.

Water.

Throughout the bottom, water is obtained either from shallow dug wells, fifteen to thirty feet deep, or by means of iron tubes driven into the ground, as deep, sometimes, as 100 feet or more.

The water always rises in the tubes to within thirty feet of the surface of the ground; in most cases to a level higher than that of the river and streams in the neighborhood; and in one instance, known to me, of a well on Indian Bayou, the water stood permanently in the tube two feet above the surface.

Generally the water is of a decidedly mineral character, especially in the very deep wells. When the tubes have been driven no deeper than twenty-five or thirty feet, the water is frequently as free from a mineral taste as the river water, though always hard.

I have made numerous analyses of the water from these driven wells, from various localities from Lower Deer Creek to the lati-

* Amer. Journ. Sci., April, 1871.

† Amer. Journ. Sci.

tude of Friar's Point, in Coahoma County, and the composition appears to be nearly the same in all.

The following is an analysis of the water from Governor Alcorn's place, near Jonestown, Coahoma County. The well is 119 feet deep. The water, when first drawn, is clear and sparkling; but soon becomes turbid, and deposits a ferruginous film upon all vessels in which it stands for any length of time.

$FeO.CO_2$	Dissolved in Free Carbonic Acid	4.877
$CuO.CO_2$		19.575
$MgO.CO_2$		17.672
SiO_2		17.482
$CaO.SO_3$		0.610
$NaCl$		1.746
$NaO, HO \} 2\,CO_2$		12.852
$KO, HO \} 2\,CO_2$		9.969
CaO, united with Organic Acid		14.665
MgO " " "		560
		100.008

Soils.

The soils of the Yazoo Bottom may be arranged into five classes, which differ materially from each other in fertility, as well as in general physical properties: the differences in their chemical composition are very striking, as may be seen by reference to the table.

First. A light-colored sandy clay, of close texture, with a few yellow spots. The growth upon this soil is swamp-chestnut oak, chiefly; with sweet-gum, ash, maple, willow oak, and an undergrowth of cane.

This soil forms the "white lands," which are not considered very fertile. It occurs on Silver Creek, east of Sunflower River, and on Indian Bayou, west of the same; and is common in the vicinity of the Sunflower on both sides, and forms most of the cultivated lands on the banks of the bayous that have their courses at right angles to the Sunflower.

I. INDIAN BAYOU FRONT-LAND SOIL, SUNFLOWER COUNTY.

Insoluble Matter	87.898
Silica, soluble in NaO. CO_2	4.036
Potash	.226
Soda	.116
Lime	.153
Magnesia	.256
Brown Oxide Manganese	.048
Peroxide of Iron	1.848
Alumina	2.565
Phosphoric Acid	.162
Sulphuric Acid	.042
Volatile Matter	3.013
	100.363

Second. A dark gray sandy loam, forming the "front-land" of many of the creeks and bayous. It is fertile, and easily cultivated. The growth is honey-locust, hackberry, and sweet-gum; and, where entirely above overflow, dogwood is a very common tree. I may add, however, that the dogwood ridges are inferior in fertility to others, where the soil is a similar dark gray sandy loam.

II. DOGWOOD RIDGE SOIL, J. L. ALCORN'S PLANTATION, COAHOMA COUNTY.

Insoluble Matter	83.886
Silica, soluble in NaO. CO_2	7.022
Potash	.392
Soda	.086
Lime	.259
Magnesia	.596
Brown Oxide of Manganese	.086
Peroxide of Iron	2.691
Alumina	3.593
Phosphoric Acid	.142
Sulphuric Acid	.010
Volatile Matter	2.007
	100.770

Third. A light gray sandy loam, with yellowish and orange streaks. The loam is sometimes of a light yellow color.

This forms the immediate banks of the Sunflower River, Tchula

Lake, and is a soil of frequent occurrence. It supports a growth of sweet-gum, maple, willow-oak, elm, and hackberry.

III. Sunflower River, Front-land Soil, Issaquena County.

Insoluble Matter	71.164
Silica, soluble in NaO. CO_2	13.506
Potash	.401
Soda	.191
Lime	.406
Magnesia	.696
Brown Oxide Manganese	.011
Peroxide of Iron	3.845
Alumina	6.889
Phosphoric Acid	.165
Sulphuric Acid	.016
Volatile Matter	2.748
	100.038

Fourth. A light gray clay, traversed by cracks, and crumbling, where exposed to the weather, into fragments, — "buckshot."

This clay differs in color and fertility, from the dark gray "buckshot" clay, which has made Deer Creek so celebrated. The growth is the same as that of No. II.; locality also the same.

IV. Light Gray "Buckshot" Clay, J. L. Alcorn's, Coahoma County.

Insoluble Matter	75.518
Silica, soluble in NaO. CO_2	10.895
Potash	.606
Soda	.146
Lime	.386
Magnesia	.972
Brown Oxide Manganese	.133
Peroxide of Iron	2.804
Alumina	4.457
Phosphoric Acid	.278
Sulphuric Acid	.007
Volatile Matter	4.401
	100.598

Fifth. A stiff, dark gray clay, sometimes nearly black, traversed in all directions by cracks, and full of streaks and dots of ferruginous matter. This is the "buckshot" clay, *par excellence*, and

forms the most fertile soil in the bottom. This and the preceding are Port Hudson clays, and form the "back-lands" and surface soil of most of the swamps lying between the water-courses. They are for the most part subject to annual overflow, though there is usually a strip one-half to three-fourths of a mile wide on the banks of the streams, under cultivation. The growth is sweet-gum, overcup-oak, willow-oak, and water-oak, hackberry, pecan; near the banks of the streams, an undergrowth of cane, but in the low, swampy back-lands, no cane, but regular cypress glades.

V. Deer Creek "Buckshot" Soil, Virgin, Harder Place, Issaquena County.

Insoluble Matter	51.063
Silica, soluble in NaO. CO_2	20.707
Potash	1.104
Soda	.325
Lime	1.349
Magnesia	1.665
Brown Oxide Manganese	.119
Peroxide of Iron	5 818
Alumina	10.539
Phosphoric Acid	.304
Sulphuric Acid	.024
Volatile Matter	7.369
	100.383

The close correspondence, between the results of chemical analysis and of the experience of farmers, would seem to indicate that the chemical analysis of soils is not without its value as an index of their fertility; though some high authorities are arranged on the opposite side of the question.

A series of analyses, some 200 in number, made at the University of Mississippi, of soils from different parts of the State, shows a similar close correspondence.

4. Remarks on the Geological Map and Section of the Rocks of Missouri. By G. C. Swallow, of Columbia, Missouri.

(Abstract.)

It was his object to put on record some of the general results of the Geological Survey of Missouri made by himself and his able assistants (one of whom, Dr. B. F. Shumard, is now dead). Since the interruption of the survey by the late civil war, there has been no opportunity offered for the publication of the results.

The survey was most minute and carefully made, and the results the same as represented by the section and map before us. The boundaries of the formation, save in eight or thirteen counties, are accurate; and all the formations are as delineated by the section running through all the great systems known to American geology.

Some of the results in Economical Geology were mentioned.

There are twenty-seven thousand square miles of coal measures, containing at least twenty coal-beds, one at least of the block coal. Large deposits of specular, hæmatite, bay, and spathic ores were mentioned. The mineral regions containing mines of lead, zinc, cobalt, nickel, and copper, cover an area of about eight thousand square miles; all but two hundred square miles in the magnesian limestone series (of the Potsdam and calciferous ages) and two hundred square miles at Granly, in the lower carboniferous rocks. Lead and zinc often cut the coal-beds in their vertical veins.

The Potsdam sandstone rests non-conformably upon the azoic stratified slates of Pilot Knob. Hence Pilot Knob.

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5. On Eozoön Canadense in the Crystalline Limestones of Massachusetts. By L. S. Burbank, of Lowell, Massachusetts.

The limestone deposits, here referred to, occur in the band of granitic gneiss which extends in a south-westerly direction from near the mouth of the Merrimack River through the entire breadth

of the State, and includes the well known mineral localities of Bolton, Boxboro', and Chelmsford.

Soon after the discovery of *Eozoön Canadense* by Mr. Bicknell, in the serpentine limestone of Newbury, it was also identified by Dr. Dawson in specimens collected by me at Chelmsford; as noticed by Dr. Hunt in the "American Journal of Science" for January, 1870. The specimens then examined were not from the rock in place, but were obtained from some outlying masses near one of the quarries. These discoveries led me to make a further examination of several of the old limestone quarries in the same formation. The eozoönal rock was then found in place at several of the quarries, and its position in relation to the other rocks observed.

At all the quarries the limestone has been so thoroughly exhausted, that the limits of its extent at the surface can be readily traced. The relations of the limestone to the enclosing rocks can thus be easily seen.

By the careful study of these relations, and by reference to many specimens collected and facts observed, the following conclusions have been reached:—

1. *These limestones are not true stratified rocks laid down with the gneiss, but are subsequent deposits of a vein-like character.* The fact that some of the deposits appear to be interstratified with the gneiss, and also are found along a line apparently coinciding with the strike of the strata, may seem to indicate that they are parts of original strata included in the gneiss; but their position may also be explained in accordance with another theory, in support of which I shall offer some evidence.

2. *The principal deposits occur along the line of an anticlinal, filling cavities produced by the folding and the falling down of portions of the included strata of the gneiss.* The anticlinal position is most clearly shown at Chelmsford, where there are four veins or masses of the limestone, in two lines coinciding with the strike of the gneiss.

These lines are about half a mile apart, extending in a north-east and south-west direction; the strike, as observed by the compass, being north 65° east. The strata of the gneiss dip in opposite directions from these lines; toward the north-west at an angle of about 65°, to the south-east at an angle varying from about 70° to a nearly vertical position.

The deposits are all of very limited extent, the largest being at

the surface not more than two hundred and twenty feet in length, and about sixty feet in width, including the intervening bands of gneiss.

The aggregate length of all the limestone deposits that occur along a line of some twenty-five miles in length is probably less than one thousand feet.

The vein-like character of the limestone is most plainly shown in one of the abandoned quarries in Chelmsford. The deposits here occur in two principal veins extending in the direction of the strike of the strata to about two hundred feet in length. The structure here plainly shows that cavities which have become filled with the limestone were formed by the folding and faulting of the strata of gneiss. The masses of limestone are separated by strata of gneiss which are also folded and arched over, enclosing cavities filled with the limestone.

At one of the quarries it can be seen that the limestone rested against the irregularly fractured ends of strata of gneiss, which fill a small space in one of the excavations, completely dividing the limestone into two masses.

That the limestone was deposited in cavities mostly closed at the top, which have since been uncovered and exposed at the surface by the denuding action of the drift, seems to me a reasonable deduction from the facts observed.

It is worthy of note that the gneiss of the enclosing walls of the cavities, and that of the dividing bands and the projecting masses nearly enclosed by the limestone, — is all of the same character with that of the surrounding strata not adjacent to the quarry.

In the direction of the strike of the strata also, at a few yards distance from the quarries, the common rock of the region is found with apparently no traces of calcareous matter. In the line along which most of the quarries occur, there are intervals of several miles where no traces of limestone have been found, though the ledges are exposed at the surface in numerous places.

The central and principal part of the mass which filled the veins and pockets and constituted the bulk of the deposit, was *a coarsely crystalline magnesian limestone, homogeneous in structure, and showing no traces of stratification.* In examining numerous specimens of this limestone from the different quarries, I have found in it no traces of the eozoönal structure.

The various silicates which form the large number of distinct

minerals for which these localities are noted, occur only *attached to, or near, the enclosing walls of the cavities*, and generally in bands or layers, though sometimes irregularly distributed. They are found generally in pretty regular succession. A network of interlacing crystals of actinolite, with smoky quartz, calcite, and phlogopite, may be seen attached to the walls; and passing inward there are found pyroxene, scapolite, apatite, boltonite, fine fibrous tremolite, &c.; and also green serpentine in irregular bands or layers, traversed by narrow seams of chrysotile; or scattered through the rock in irregular rounded grains and masses, with intervening spaces filled with calcite.

In these portions of calcite are found the radiating and branching forms that have been identified and described as belonging to the structure of eozoön. The granules of serpentine are sometimes arranged quite regularly in concentric lines, but more commonly appear irregularly scattered and varying indefinitely in form and size.

Some of the specimens from Chelmsford show masses of the serpentine intersected by narrow seams of chrysotile, and attached to portions of the rock in which the decalcified spaces exhibit the tubuli in great abundance, *attached to the serpentine grains as if growing out from their surfaces.* Some of the grains are surrounded by a fibrous layer, closely resembling the "true cell wall" of eozoön as I have seen it in the Canadian specimens. The surfaces of many of the grains are covered with acicular crystals penetrating the calcite. Some of these, as they extend into the calcite, become rounded and curved, losing the acicular character.

In nearly all the specimens examined, bundles of acicular fibres, apparently of tremolite, are scattered abundantly in the calcite.

In some portions of the rock the serpentine appears embedded in the limestone in definite crystalline forms, apparently pseudomorphs of chrysolite, or boltonite. In the quarries of Boxboro' and Carlisle, cinnamon garnet is abundant, associated with scapolite and green pyroxene or coccolite, with calcite. I have examined the calcite of many of these specimens for traces of the eozoönal structure, but, so far, with negative results. In fact, so far as I have observed, the tubuli invariably occur in the rock associated with serpentine.

Some facts have been stated in this communication for which I offer no theories in explanation. I do not claim a sufficient knowledge of the foraminifera to found any argument upon the micro-

scopic appearances that I have observed, nor do I mean now to enter into a discussion of the general question as to the true character of the *Eozoön Canadense*, as described by Carpenter and Dawson.

I am unable, however, to reconcile the facts here stated with the theory that the forms in these rocks, which have been identified as belonging to the structure of eozoön, are of organic origin.

On the other hand, it appears to me not unreasonable to infer that the so-called "tubuli" that are so abundant in these rocks, *are semi-crystalline forms that have been deposited with the serpentine and other minerals on the walls of the cavities*, by infiltration of waters charged with mineral matters.

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6. The Precise Geographical Position of the Large Masses of Meteoric Iron in North Mexico, with the Description of a New Mass — the San-Gregorio Meteorite.

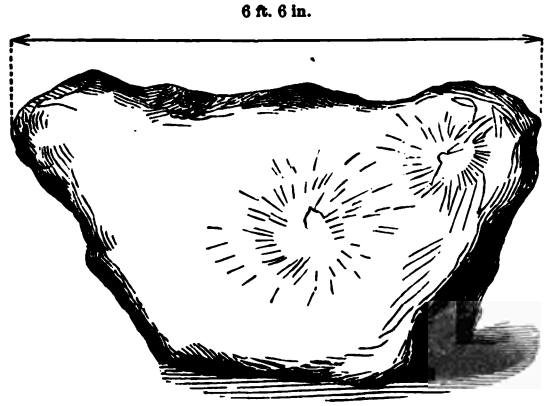
By J. Lawrence Smith, of Louisville, Kentucky.

Some of the remarkable masses of meteoric iron in northern Mexico have been known to travellers for a number of years; but no very precise information concerning them had been given until the year 1854, when the first mass, brought from that locality, was placed at my disposal by Lieutenant Gouch, of the United States army, and was described in a memoir on meteorites published in the "American Journal of Science," April, 1854; it is now in the Smithsonian Museum, and weighs 252 pounds.

On the return of Mr. Bartlett, of the Boundary Commission, I learned of two other masses in that region, and Lieutenant John G. Parke, of the United States army, placed a fragment of one of them in my possession; the fragment of the other mass was lost. I figured and described both of those meteorites in the memoir just alluded to; the first, which I called the *Tucson Meteorite*, is now in the Smithsonian Institution, and weighs, I believe, several thousand pounds; the second one I called the *Chihuahua iron*, and it is still at the *Hacienda de Conception*, where it was first found. Still later, in the year 1868, Dr. H. B. Butcher placed under my

examination eight masses of meteoric iron that had been brought to the United States from the same region of Mexico; these I examined, and published a full account of in the "American Journal of Science." These masses are now in Philadelphia, still owned by Dr. Butcher, and vary in weight from about 300 pounds to 800 pounds. Dr. Butcher having returned to Mexico, I requested him to get all possible information in regard to the geographical position of these bodies; this he has succeeded in accomplishing. At the same time he has a fragment of another mass, still larger than any yet known, which will be called the *San-Gregorio Meteoric Iron.* Its description is as follows: —

The San-Gregorio Meteorite. — This immense mass of meteoric iron is situated on the western border of the Mexican Desert, a



map of which is given on the next page. Some idea of its form may be had in the accompanying sketch.

It measures six feet six inches in its greatest length, is five feet six inches high, and four feet thick at its base; on one part of its surface, 1821 is cut with a chisel, and above this date is the following inscription: "*Solo dios con un poder este fierro destruerá, por que en el mondo no habra quien lo puedo deschacer.*"

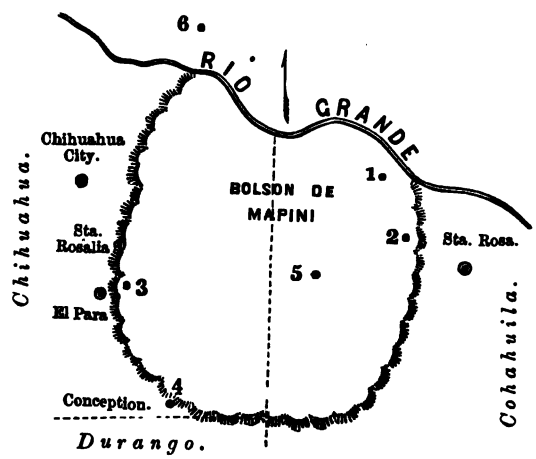
It lies within the inclosure of a hacienda, having been hauled to the ranch many years ago by the Spaniards, who thought that it could be made use of as iron for farming utensils. It is said to have fallen quite near its present site, and from its huge bulk and weight, which is calculated to be about five tons, it could not have been transported very far. Nothing more is known of its history.

Small specimens were detached by Dr. Butcher, one of which I have examined. I find it to be of the softer meteoric irons, with a specific gravity of 7.84. The fragment I possess is too small for the study of the true character of its Widmannstätian figures.

On analysis, it furnished the following composition: —

Iron	95.01
Nickel	4.22
Cobalt	.51
Copper	minute trace
Phosphorus	0.08

This *San-Gregorio* iron makes the fifth that has come under my observation and examination from this famous Mexican locality, the geography of which I will now describe, referring to the accompanying diagram for details.



The Bolson de Mapini or Mexican Desert occupies the western portion of the province of Cohahuila, and the eastern portion of the province of Chihuahua. It is 400 miles from east to west, and 500 miles from north to south, bounded on the north by the river Rio Grande. Some of the villages and haciendas are specified in the diagram, and the numbers 1, 2, 3, &c., are the localities of the different meteoric masses discovered.

No. 1. The locality of the *Cohahuila* meteorite described by me in the "American Journal of Science," April, 1854; it is now in the Smithsonian Institution.

No. 2. The locality of the *Cohahuila* meteorite of 1868, described by me in the "American Journal of Science," April, 1870; it is now in the possession of Dr. Butcher.

No. 3. The locality of the *San-Gregorio* meteorite just described; it is still in the place where it was first observed.

No. 4. The locality of the mass described and figured in my memoir on meteorites ("American Journal of Science," April, 1854), and called the *Chihuahua Meteorite;* it is still in place at the *Hacienda de Conception*, ten miles from Zapata, its greatest height being forty-six inches, breadth thirty-seven, and in the thickest part eight feet three inches in circumference. Signor Urquida calculated its weight to be about four thousand pounds.

No. 5. The locality of a huge meteorite lately discovered, of which no specimen has yet been detached, and which is said to be larger than any one yet found in that locality.

No. 6. The locality of the large mass described and figured by me in 1854 as the *Tucson iron*, and now in the Smithsonian Institution at Washington, having a large hole in the centre, and sometimes called the *Signet Meteorite*, also the *Ainsa Meteorite.* I do not know its exact weight, but suppose that it must weigh two or three thousand pounds.

The question naturally arises, What can be the cause of the number of meteoric masses in the circumscribed region, and whether each one represents a separate fall? My study of them leads me to the belief that they are the products of two falls. First of all, No. 6, the Signet or Ainsa meteorite, has peculiar physical and chemical characters that separate it entirely from the others. Nos. 1, 2, and 3, I have examined chemically, and find them very closely allied in composition, also in physical properties, as the softness of the iron and freedom from rusty crusts over the exterior; in fact the pieces I have examined were more or less bright on the exterior surface. The Widmannstätien figures I have not had an opportunity to compare, since, with the exception of No. 1, I have had only small pieces that were detached from the surface by a cold chisel, which are unfit for the study of these figures. Thus far in my investigation, there appear strong reasons for supposing that at some epoch, probably far remote, the meteoric masses 1, 2, 3, 4, and 5, were the products of the fall of one meteoric mass, moving from the north-east to the south-west, the smaller masses falling first at 1 and 2, and the larger masses farther on. The distances of these bodies from each other are: from Nos. 1 to 2,

about 85 miles; from 2 to 5, about 135 miles; from 5 to 3, about 165 miles; from 3 to 4, about 90 miles. Of course there is no great stress laid upon these deductions, but it would not be surprising if further investigation should sustain this view.

Since my first publication on these meteorites, Burckhardt, of Bonn, has made some observations upon them, but his publications are not within my reach at the present time.

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7. On the "Eozoön" Limestone of Eastern Massachusetts.

By John B. Perry, of Cambridge, Massachusetts.

It is perhaps fitting for me to present a short paper on the "Eozoön" limestone of Eastern Massachusetts, since I have been long engaged in the study of the Foliated (or Laurentian) series of rocks, in which it occurs; insomuch, also, as I discovered, many years ago, what seemed to me indubitable evidence that portions of this limestone are of vein-like origin; and because I was the first to suggest, and really to make out, that some of the limestones of Eastern Massachusetts have a similar vein structure. It likewise properly devolves upon me to say something at this time, since, after visiting Chelmsford, and satisfying myself in regard to the actual character of the calcareous masses containing the so-called organic remains, I agreed to present some of the more important points bearing on the stratigraphy of the rocks, whenever my friend, Mr. Burbank, of Lowell, should be ready to discuss the existing evidence, and especially that furnished by the microscope, as to the organic character of the enclosed "Eozoön."

As geologists have generally supposed that all limestones are stratified rocks, a few preliminary words may be requisite on this point. They are more especially needful at the present time, and in connection with the subject under consideration, as they may serve to meet an objection which is likely to occur to many minds, — particularly such as hold to the organic or "sedimentary" derivation of all limestones. It is true that Dr. Emmons, as is well known, endeavored to show that limestones occur, not only as

stratified beds, but also as intrusive masses; but this doctrine was never widely received, however much truth may have lain concealed at its foundation. Beginning my study of the limestones connected with the Foliated series of rocks, in the light of this view, I finally became convinced in 1861, and so set forth in a course of lectures delivered during the same year, that some of these limestones in Vermont and New York have a vein-like structure, and should be regarded as true vein-stones. Having entered anew, some four or five years ago, upon the study of the rocks of eastern Massachusetts, I at once became convinced that limestones in Stoneham, Newberry, and some other townships in the easterly portion of the State, are also vein-rocks.

Such limestones are to be met with, as has been in part already implied, in association with the Foliated series of rocks, both in eastern and western Vermont, and in various different parts of Massachusetts. They also occur among the Adirondacks of New York. Limestones of this character — hand specimens of which can be scarcely, if they can be at all, discriminated from given samples of stratified Silurian limestones — are likewise found in Vermont, New Hampshire, and elsewhere, in the form of dikes. In most of these cases, close examination clearly shows, and perhaps it will hereafter as clearly evince in them all, that the dike-like masses were formed in a vein-like way, by gradual deposition, extending from the enclosing walls toward the centres of what once were cavities. Similar masses of calcareous vein-stone are to be met with in St. Lawrence County, New York, and in some other localities, penetrating beds of sandstone. Indeed, were there time, it would not be difficult to show that rocks of this character may be found in association with formations of greatly varying, if not of almost every age.

These and other similar cases, which might be readily cited, are suited to remove the objection that all limestones are stratified rocks, and show that no one can reasonably look for, or expect to find, organic remains in any such masses. Having made out the points just advanced, years ago, in regard to some of the so-called primitive, or saccharoidal limestones, I have been sceptical ever since in respect to the supposed organic nature of the "Eozoön." Accordingly, on the announcement, in August, 1869, of the discovery of this strange form in the limestones of Newberry, I at once discredited its assumed organic character, — discredited the assumption, that it represents, as its name indicates, the dawn of

amimal life on the globe, — on the ground, among other reasons, of its occurrence in calcareous masses of a vein-like origin. Of course, on hearing, a few weeks later, of a like discovery in Chelmsford, and seeing a specimen of the rock holding the supposed organic forms, I was prepared, by my previous experience, for a similar conviction in respect to the matter involved in the new announcement. This I immediately expressed, in one of the lectures on the Foliated rocks, which I was then delivering in course; and I was fortunately able fully to confirm my impression, by personal examination, on going to the quarry several months later with Mr. Burbank, who had previously, and has since, devoted himself, with commendable assiduity and care, to the study of the rocks of these older formations.

On visiting the Chelmsford quarries, and observing what had been before considered, and at first sight might be readily taken, as evidence of stratification in the limestone, I was able, because of earlier studies in this direction, at once to detect the falsity of the inference that had been drawn, and to indicate, what all the evidence thus far gathered shows to be, the true nature of the mass in question. I found, and have since substantiated by various and careful cross-examinations, what the advocates of the organic structure of the "Eozoön" seem never to have suspected, that the limestones under consideration are not to be regarded as stratified masses at all; that, while they may appear, on casual inspection, to be laminated, they are really foliated, and the appearance of stratification is thus to be accounted for in another way; and that, being unstratified, they are not either almost altogether, as has been affirmed of many such rocks, or in any degree, made up of organic remains. These calcareous deposits, as should be constantly borne in mind, do not occur in an uninterrupted line, or crop out in ranges at all uniformly continuous, as is usually the case with sedimentary beds. They are isolated masses, generally of greatly varying size, — though, in the Chelmsford series, more uniformity may be observed in this particular, — and, as ordinarily found upon the surface, they almost invariably appear only at irregular intervals.

It should be also remarked, that the limestones at Chelmsford, like other kindred masses, are of a lenticular shape. They occupy, or rather they once occupied — for the lime rock has been mostly removed for economical purposes — pockets, irregular and uneven cavities, or in most cases oven-shaped spaces, more or less lenticu-

lar, which were clearly produced by the disturbance of the main formation. This, at Chelmsford, consists almost entirely of gneiss and of gneissoid rocks. The cavities containing the limestone were once plainly overarched by the accompanying gneiss. In places the gneiss now so overarches some of them, and it beyond question so overarched them all before denudation took place, as to make it evidently impossible that extraneous fossils, or any other solid foreign bodies, could have been carried in, and deposited in a continuous series, beneath the summits, and all along the sides, of the gneissic arches.

Again, these lenticular masses of limestone have that banded structure, which is peculiar to one class of veins. They are foliated in the strict sense of the epithet, there being a series of leaves or of leaf-like layers, and these having a regular sequence, from the walls toward the centres of the cavities. And to this succession peculiar evidence is borne; for there is associated with the successive bands a like succession of different minerals. The orderly occurrence of these minerals — Mr. Burbank, I believe, was the first to notice their presence in the limestone, on a previous visit — is a striking feature, which may be verified by any visitor who is disposed to be sufficiently pains-taking to go through with the task; while it is certainly well deserving of attention, both in itself considered, and because of the witness it bears in various directions. Indeed, the foliated structure with its accompanying series of mineral substances, each occurring in a determinate order, evinces that the process of veinous deposition was gradual, and probably long continued; that time enough must have elapsed for one set of ingredients to be brought in and deposited, — for fresh supplies containing some new elements, to be introduced and exhausted, — for these, again, to be superseded or at least supplemented by additional and somewhat varying materials, themselves to be in their turn fixed upon the walls in leaf-like layers; also that one of these layers succeeded another, in regular gradation, from the sides of the cavities toward the centres, until all the interior spaces were finally filled; and that, consequently, the apparent stratification is due, not to aqueous deposition as ordinarily understood, but to the vein structure of the calcareous deposits.

Once more, it should be remarked that limestone veins, and various irregular apertures filled with carbonate of lime, of a smaller size than the main cavities already noticed, may be detected here and there in the walls of the adjoining rock. Indeed,

a careful inspection of the quarries reveals the occasional presence of calcareous matter in what were perhaps once minute clefts, cracks, and crannies in the surrounding gneiss; the presence of matter, which was no doubt introduced into all the smaller crevices, in connection with the deposition of the principal masses of limestone, but long after the formation of the main gneissic rock. This calcareous material which, in places, may be now seen ramifying, in a vein-like way, the walls that form the chief cavities, was evidently connected, at some former period, with the larger masses of limestone. Such veins, while they are not numerous, or likely to be noticed without careful scrutiny, are of great interest and very significant.

But this is not all; there is other, and what to some will perhaps be more explicit, testimony to the former prevalence of a vein-forming agency. An accurate observer, even the casual visitor, will hardly overlook the marked conformity of the limerock with the gneiss, — a conformity which suggests that the former, while in a plastic state, was moulded upon the latter. Indeed, after careful inspection, one can scarcely fail to note that, generally, the calcareous bands exactly conform with the most abrupt irregularities and jagged inequalities in the surface of the enclosing walls, and by no means less so with the occasional breaks which may be seen in them; that the deposit was everywhere so made, in consonance with the adjoining rock masses, as to reveal its more recent origin, in connection perhaps with the action of various mechanical and chemical agencies; and therefore that, instead of being largely made up of the calcareous remains of Rhizopods, it is not at all of a foraminiferous derivation, but took its place in a vein-like way, — the materials having been probably, either forced up from below in a heated state, or introduced from above in the form of an aqueous solution.

In confirmation of the view presented, reference ought to be made to the limestones holding "Eozoön" in other localities, and apparently belonging to the same part of the series of Foliated rocks, as well as to what seem to be kindred calcareous masses subordinate to formations of a very different character. Did time allow, I should also especially like to refer to other limestones that are probably closely akin, but perhaps of somewhat varying age, — limestones, which I have repeatedly examined, in their several places of occurrence, — though they be not known to hold "Eozoön." Waiving the consideration of these instances, I may, in a word, simply call attention to some of the calcareous masses in Stone-

ham, Massachusetts, because they are intensely interesting, as suited both to reveal the processes which have been at work in their own formation, and to suggest what has taken place in kindred rocks not so easily known; for they have a vein structure, like that of the limestones at Chelmsford and Bolton. This structure, which seems to be common to the several rocks mentioned, is doubtless due to the operation of the same, or of closely allied causes. Portions of these calcareous masses I have found penetrating the adjoining Syenite — for with this rock, in Stoneham, they are more particularly associated — in a vein-like way. This limestone also conforms exactly with the most ragged and broken surfaces, even with all the most diverse inequalities, of the adjacent Syenitic rocks. In short, it is so situated in relation to them, as clearly to reveal its more recent origin.

Such are a few of the more important points characteristic of the calcareous masses, in Eastern Massachusetts, which are known to hold "Eozoön," — points, which should be verified by an actual examination of the masses in question, and of similar rocks so far as accessible, and as they occur in place. Whether all the limestones noticed be exactly identical in origination, in structure, and in age, or not, they certainly have very many features in common, and are so essentially alike, if one may judge from their appearance, as to serve well to illustrate each other. The question as to the mode of their origin, whether it were by infiltration, segregation, or sublimation, I leave undiscussed for the present, — proposing to take it up in detail, on some future occasion. Enough, I think, has been said to show that the limestones to which reference has been more especially made, and particularly those of Chelmsford, have truly a vein-like structure, and are really vein-rocks.

But there is another point, of no small importance, to be briefly noticed. It is a fact, which no one can successfully gainsay or deny, that genuine "Eozoön" — "Eozoön" which has been recognized and is accredited genuine by those who hold to the organic nature of this marvellous form, and as advocating it are supposed to be best qualified to judge of its character — actually occurs in great profusion, in some of the limestone of Chelmsford. Of this rock Mr. Burbank has now on exhibition authentic specimens, in large variety; specimens collected with thoughtful discrimination by himself, and in respect to the genuineness of which there is no doubt; specimens, some of which give a good view of the structure, and reveal various important features, characteristic of a form which

very many have regarded as of animal origin; specimens, in sections, carefully prepared for the microscope, to which attention is especially invited, and which all who are disposed are at liberty to examine at leisure.

Thus an important problem is proposed, a problem of very manifold bearings, and now demanding a reasonable solution; a problem involving difficulties not easily explained, suggesting queries not readily answered, and imposing a task not likely to be speedily achieved, in consistency with widely received views of this strange fossil form. The fact that genuine "Eozoön" occurs in these calcareous masses, under the conditions which have been just passed in review, surely brings before us an enigma of marvellous import, if all that has been said of it be true; the enigma of the occurrence in vein-stones, in almost endless profusion, of a form asserted to be representative of the dawn of animal life upon our planet; an enigma, however, which is apparently inexplicable on the hypothesis that the form is organic, and which I accordingly leave for those who are professedly conversant with "Eozoönal" structure to explain as best they are able. Meanwhile the evidence now presented, among many other special bearings, forces upon us one in particular which ought not to be overlooked. It evinces, so far as it is readily possible to evince, the inorganic character of the limestones under consideration. And while it seems thus clearly to show, that the so-called Eozoön of Chelmsford is not an organic structure, it at the same time indicates the probability that the "Eozoönal" forms furnished by limestones of the Grand Calumet in Canada, of Bavaria and Bohemia, of Ireland and of other regions, have the same or a kindred origin, and therefore that they are likewise inorganic. Indeed, so far as I can see, the evidence casts discredit upon the assumed organic character of the "Eozoön" generally, and fixes the burden of proof upon its advocates, to whom it originally belonged, and with whom of good right it should have always remained. It also with equal certainty suggests that the resemblance which the "Eozoön" bears to animal structure, is, like that of "Dendrites" to vegetable forms, merely the result of chemical agency; in other words, that the "Eozoön" properly belongs to the department of Mineralogy, and not, as has been claimed, to that of Palæontology.

II. ZOÖLOGY.

1. On the Carpal and Tarsal Bones of Birds. By Edward S. Morse, of Salem, Massachusetts.

The author stated that he had followed with great interest the work of Huxley, Cope, and others, in tracing out the ornithic character in the Dinosauria. While following these relations, he had noticed a marked difference in the characters of the two classes. It seemed strange that a group of bones so persistent in the reptiles, as well as in the mammalia, should be so obscure, or wanting, in birds.

Owen objects to the term *tarso-metatarse*, as he believes the existence of a tarsus has not been demonstrated. W. S. Parker, in 1861, on the osteology of the Balæniceps Rex, queries if the lower articular portion of the tibia is not the homologue of the mammalian astragalus, and not an epiphysis.

Gegenbaur has now shown that, in an early stage of the chick, there is a proximal tarsal ossicle, and a distal tarsal ossicle; the proximal one anchylosing with the tibia, the distal one likewise anchylosing with the metatarsus. Thus, the term tarso-metatarsus is not only correct, but the nature of the segment in question is explained by it.

While this was a great step toward a proper understanding of these parts, Mr. Morse believed that a nearer relation would be found in the discovery of another proximal tarsal bone. In reptiles, — even in the low Batrachians, — however few in number the tarsal bones might be, there were always in the proximal series one corresponding to the tibia, and another corresponding to the fibula.

He had found this feature in birds. The following embryos were studied: —

Bank Swallow, *Cotyle riparia.*
Cave Swallow, *Hirundo lunifrons.*
King Bird, *Tyrannus Caroliensis.*
Crow Blackbird, *Quiscalus versicolor.*
Cow Blackbird, *Molothrus pecoris.*

Bluebird, *Sialia sialis*.
Chipping Sparrow, *Spizella socialis*.
Yellow Warbler, *Dendroica æstiva*.
Wilson's Thrush, *Turdus fuscescens*, and the
Spotted Sand-piper, *Tringoides macularius*.

In these he had found three distinct tarsal bones, — two in the proximal series answering to the astragalus and calcaneum or the *tibiale* and *fibulare* of Gegenbaur, and one in the distal series representing the *centrale*.

The first two anchylose at an early stage, and present an hour-glass-faced articular surface, as described in the astragalus of Lœlaps by Professor Cope. The final anchylosis of these conjoined ossicles with the tibia formed the bicondylar trochlea so peculiar to the distal end of a bird's tibia.

The distal tarsal ossicle became united with the proximal ends of the metatarsals as Gegenbaur had shown.

In the carpus he had found four perfectly distinct ossicles, — two in the proximal series, and two in the distal series; the bones of the proximal series remaining free, while the bones of the distal series unite with the base of the mid and outer metacarpal.

Thus we have in the wing, as in the leg, the joint between the first and second carpal series.

In the Kingbird and Yellow Warbler he had found a fifth carpal on the radial side.

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2. On the Mechanism of Flexion and Extension in Birds' Wings. By Elliott Coues, of Fort McHenry, Maryland.

I desire to bring to the notice of the Association, and of ornithologists in general, a certain mechanism in the wings of birds, which has not received the attention that is warranted by its interest and importance. No discovery is claimed; for probably the point cannot have been overlooked: nevertheless, having seen no account of it, I am led to believe that it will be new to many, as it was to myself when I first detected it.

I will first briefly recapitulate the well-known points of osseous

structure marking the elbow and wrist-joint of birds, that they may be fresh in the mind; and then demonstrate the particular mechanism above alluded to.

The elbow is a ginglymus, or hinge-joint, but one of a peculiar kind, inasmuch as it is *oblique;* the forearm being flexed upon the upper arm, not in a plane of the axis of the humerus, but considerably out of such plane, so that in extreme flexion the carpus does not lie against the upper arm, but below and outside of it. The shape, size, and relative position of the two humeral articular surfaces with which the ulna and the radius respectively articulate, which are diagnostic of this class of vertebrates, explain this obliquity of flexion. The surface for the ulna is hemispherical (to speak in general terms), while the radial one is semi-elliptical; and the obliquity of the major axis of the latter impresses a corresponding obliquity upon the motion of the radius in flexion of the forearm. The globular shape of the ulnar surface allows, so to speak, a sort of passive rotation of the head of the ulna, so that this bone can (and from its unyielding connection with the radius it must) follow the radius in the oblique course that the radial surface enforces. Such, briefly, is the characteristic of the avian elbow-joint, and such the teleology usually ascribed to its peculiar construction. It will appear, however, in the sequel, that, although this explanation of the size, shape, and relative position of the two humeral articulating surfaces is perfectly true, yet it does not express the whole truth; and that in the construction of the elbow-joint another and more important purpose is subserved, — one that is essential to flexion and extension *of the hand upon the forearm.*

The bones of a bird's forearm are firmly bound together, and do not permit pronation or supination in any appreciable degree. Such stability is obviously necessary to the efficiency of the wing in the peculiar office it is called upon to perform; for without unyielding connection of the bones of the forearm, the tip of the wing would fly up on the downward stroke of the member, and down on the upward stroke, unless counteracted by muscular effort that could not be effectively applied nor sustained without fatiguing effort, and consequently is not brought into play at all, — this osseous contrivance taking its place. With obvious reference to the same condition, the customary flexion and extension at the wrist-joint that occurs in other vertebrates is in birds replaced by abduction and adduction of the hand — the carpus being stiff and unyielding in the up-and-down direction, or vertical plane,

and perfectly flexible in the opposite (the horizontal) one. But as these movements are commonly called flexion and extension, we shall continue to employ the terms, remembering that abduction, which occurs in spreading the wing, corresponds to extension, and that adduction, or folding of the wing, is similarly equivalent to flexion. In the anatomy of the carpal joint, we have only to remember that, in the adult state, there are two carpal bones interposed between the forearm and metacarpus. One of these is the larger, and is an irregular osseous nodule lying on the outer (radial) border of the articulation, opposed proximately to the end of the radius, and distally to the outer (radial or thumb) border of the metacarpus; it expresses the convexity of the articulation. The other, smaller, lies on the opposite side, in the concavity of the wrist-joint; it connects the end of the ulna with the inner (ulnar or little finger) border of the metacarpus, and, being somewhat bifurcated, bestrides a ridge on the metacarpus, and rides back and forth upon the latter in the movements of the hand. Without considering the morphology of these two bones, it will be sufficient for present purposes to call the larger one the radio-carpal bone, and the smaller one the ulno-carpal bone. Finally, what is to be particularly remembered in this connection is, that the radio-carpal bone is so situated that, if it be *pushed upon* by the end of the radius, it will transmit the push to the outer, radial, or thumb border of the metacarpal, and consequently cause the distal segment of the wing (the hand) to be adducted or flexed; and, conversely, if the radio-carpal bone be *pulled upon* by the radius, or, what is the same thing, if the ulno-carpal bone be pushed upon, the reverse motion of abduction or extension of the hand will result.

It is our object to show that, in spreading and folding the wing, the radio-carpal bone is alternately pulled and pushed by the end of the radius; or, in other words, *that the radius slides lengthwise back and forth along the ulna;* that this peculiar motion is primarily effected at the elbow, and is directly due to the size, shape, and position of the humeral surface with which the radius articulates. The main proposition, which has several interesting corollaries, may be thus stated: —

THEOREM: *Extension of the forearm upon the humerus causes extension of the hand upon the forearm by osseous mechanism alone; and, conversely, flexion of the forearm effects corresponding flexion of the hand.*

For, the wrist being connected with the elbow by two bony rods, any alteration in the relative position of the rods, that may be effected by pulling or pushing upon one of them (the other remaining stationary) at the elbow, will be transmitted to the wrist. In a given position of the bones of the forearm with reference to the humerus,— say the position of extension — the surface that the ulna articulates with will be *nearer* the carpus, than the surface that the radius articulates with is, in consequence of the inferior position of the surface that the ulna articulates with. In another position — say of flexion — the surface that the radius articulates with will be nearer the carpus, in consequence of the superior position of this surface. The two bony rods remaining of the same lengths in any position, it follows that these differences in the relative positions of their proximal ends will be transmitted to their distal ends, and there repeated exactly (saving only with such variation as the difference in the contour of the ends of the bones may effect). That is to say, in extension of the forearm upon the arm, the radius is in effect pulled away from the carpus, in consequence of its articulation with the humerus at a surface further removed from the wrist; and, in flexion of the forearm, the radius is pushed forward upon the carpus, since its humeral articular surface is then nearer the wrist. Now, since the end of the radius abuts against the radio-carpal bone, which lies upon the outer or thumb border of the metacarpal, it follows that when the radius is pushed forward, the motion thus transmitted to the hand will make the latter swing around the centre of motion of the wrist-joint; and that, when the radius is pulled back, the reverse motion will be impressed upon the hand; and, further, that these motions are respectively adduction or flexion, and abduction or extension. So, therefore, flexion of the forearm effects flexion of the hand, by osseous mechanism alone, and conversely. *Q. E. D.*

This mechanism is illustrated in the accompanying figures, which, although not strictly accurate,* show the points involved very well. Fig. 3 represents the front view of the lower end of the left humerus, in which the smaller, globular articulating surface for the ulna is seen to be lower down on the humerus than

* The artist has not represented complete flexion or extension, as was desired, and has somewhat exaggerated the amount of difference in the relative position of the ulna and radius, that occurs in the two positions. The bones are of a fowl's wing.

the other, and consequently nearer the carpus when the latter lies in a line with the axis of the humerus; and the larger elliptical surface for the radius is seen to be both more protuberant and higher in position, and thus for two reasons to be nearer the carpus when the latter is swung around towards the shoulder. Figs. 2 and 1 show the elbow-joint and forearm bones (in half profile) in two positions. In Fig. 1, where the forearm is extended, the ends of the radius and ulna are nearly in the same plane. In Fig. 2,

where the forearm is flexed, the end of the radius projects over the end of the ulna; and in each case the relative position of the ulna and radius is seen to depend upon the position of the two humeral articulating surfaces.

The proposition may easily be demonstrated experimentally. On cutting open the carpal joint of a fowl, across the ends of the forearm bones, so as to leave the two carpal bones attached to the metacarpus, and then alternately extending and flexing the forearm, the end of the radius will be seen to ride back and forth upon

the end of the ulna; and the radio-ulnar plane of the carpal articulation will change its position according to the position of the forearm with reference to the humerus.

The first corollary of this proposition is too obvious to need demonstration. It is simply, that flexion and extension of the hand must follow the same motions of the forearm.

That the sliding of the radius along the ulna which has been demonstrated is absolutely necessary to the anatomical integrity and proper function of the wrist-joint, is a second and important corollary. For, in folding and unfolding, the point of the wing sweeps through an arc of nearly 180°; that is, the hand is carried from a position nearly parallel to, and side by side with the forearm, to one nearly in a straight line continuous with the long axis of the forearm; and, furthermore, this motion, being of adduction and abduction, occurs in the longest diameter of the carpal articulation, instead of the shortest, which would be the case in true flexion and extension.* Now, since the carpal ligaments are all inelastic and unyielding, it follows that if the ends of the radius and ulna were bound together immovably, the carpal joint would be wrenched open, at the site of the radio-carpal bone, or point of greatest convexity, in extreme flexion of the hand; and similarly, in perfect extension of the hand, the opposite side of the wrist-joint, where the ulno-carpal bone lies, would be strained. In other words, the anatomical structure and relations of the carpus are such, that the requisite amount of flexion and extension of the hand could not be secured without that accommodation of the plane of the articulating surfaces of the radius and ulna which has been shown to result from flexion and extension of the elbow.

The third and last inference that I draw, likewise relates to the teleology of this interesting mechanism. Independently of the considerations presented in the last paragraph, another and equally important design is fulfilled: that of retaining the wing in position, both when it is folded and when it is spread, by the automatic action of the bones, so to speak, and thus of relieving the muscles that act upon the carpus, metacarpus, and phalanges, from a part of the work they have to perform. In the act of flying, and in

* To appreciate the point here meant, observe that the human hand may be flexed or extended at the wrist, so that it sweeps through nearly 180°, moving around the shortest diameter of the joint; but that its abduction and adduction, or motion sideways across the longest diameter of the carpal articulation, amounts to only about 45°.

other actions that birds perform with the wings expanded, the point of the wing must remain extended to a degree correspondent to the amount of extension of the forearm; and particularly, in all terrestrial and aquatic progression, when the wings are not used, as well as in a state of rest (and, it is hardly necessary to add, by far the greater part of a bird's time is spent in one or the other of these conditions), the weight of the distal segment of the wing is largely supported, and the point of the wing somewhat fixed in its folded position, by the flexion of the forearm upon the humerus.

Independently of the obvious anatomical necessity for some such bony arrangement as has been described, and in a purely physiological point of view, it is no exaggeration of the import of this osseous mechanism to say, that by its means the action of the brachialis anticus, biceps, and triceps, is transmitted to the very end of the distal segment of the wing; that it accomplishes a part of the work that the muscles would otherwise have to perform, and tends to equalize muscular action, by taking some of the strain off the smaller muscles that act upon the hand, and relegating a part of their work to the larger ones of the upper arm.

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3. On the Characteristics of the Primary Groups of the Class of Mammals. By Dr. Theodore Gill, of Washington, D. C.

General.

At the last meeting of the Association, the author made a communication on the classification of mammals, based on facts in part already become the common property of science, and in part previously unpublished. An abstract giving the conclusions arrived at has been published in "The American Naturalist" and in the "Proceedings" of the Association. Continued researches into the same subject have confirmed the propriety of the ordinal groups and the limits then admitted, but have necessitated a different combination of those groups.

The divisions into subclasses first solidly established by Huxley are still retained.

The Placental or Monodelphian mammals are with more propriety combinable into two major groups which correspond — on the one hand, to the EDUCABILIA of Bonaparte (the combined ARCHENCEPHALA and GYRENCEPHALA of Owen, and the combined ARCHONTS and MEGASTHENES of Dana); and on the other hand, to the INEDUCABILIA of Bonaparte (the LISSENCEPHALA of Owen and the MICROSTHENES of Dana). The characters hitherto used to distinguish those groups are, however, either vague and difficult of application, not characteristic, or generally regarded as inapplicable. But positive and easily recognizable characters appear to exist in the brain which confirm those groups, but which have not hitherto been regarded, at least in respect to their systematic application.

There has also always existed cause to deplore the insufficiency of the characters assigned in the diagnoses of some of the orders of mammals. After an attentive study of most of the known forms, the author believes that he has succeeded in finding characters which at the same time confirm the groups already recognized and supplement the teleological characters (sometimes of doubtful application or entirely failing) by morphological characters of more constancy. The revised diagnoses of the orders and other primary divisions are submitted in advance of a work now being printed by the Smithsonian Institution; that work will give the characters, contrasted in dichotomous tables, of all the groups of mammals as low as subfamilies and lists of the genera, recent and extinct. While the author has been dependent, for the most part, on the collections of the Smithsonian Institution for his investigations, he has also visited the museums of the Academy of Natural Sciences of Philadelphia, the Peabody Academy of Science of Salem, the Boston Society of Natural History, and the Museum of Comparative Zoölogy at Cambridge.

Principles of Classification.

It is proper to repeat here the principles which have guided the author in the appreciation of the relations of the various groups admitted, and their combination. These are the following five: —

I. Morphology is the only safe guide to the natural classification of organized beings; teleology or physiological adaptation the most unsafe and conducing to the most unnatural approximations.

II. The affinities of such organisms are only determinable by the sum of their agreements in morphological characteristics, and not by the modifications of any single organ.

III. The animals and plants of the present epoch are the derivatives with modification of antecedent forms to an unlimited extent.

IV. An arrangement of organized beings in any single series is, therefore, impossible, and the system of sequences adopted by genealogists may be applied to the sequence of the groups of natural objects.

V. In the appreciations of the value of groups, the founder of modern taxonomy (Linnæus) must be followed, subject to such deviations as our increased knowledge of structure necessitates.

I.

The first of these principles is almost universally accepted by scientific naturalists, although popular writers still frequently urge, as reasons for certain classifications of animals, that modifications of the general form, or of special organs, are subservient to the use of the animal; such teleological modifications, however, are really provocative of suspicion of their taxonomic significance.

II.

The second proposition is also very generally adopted by scientific naturalists, at least in practice, but my learned friend, Professor Cope, — in his very able and instructive memoir on the classification of the reptiles,* — while expressing a general approbation of the principles just enumerated, has combated the one in question; he conceives "it to be a very good expression of the views of many naturalists, yet, in [his] own, it does not go far enough; nor is the second clause, that 'affinities are determinable' 'not by the modifications of any single organ,' one with which [he] can agree. The same objection, therefore, applies to the corollary following, that the 'adoption of such principles compels us to reject such systems as are based solely on modifications of the brain, those of the placenta, and those of the organs of progression,' &c. In other words, agreeing with the first part of Proposition II., that 'affinities are only determinable by the sum of their agreement in morphological characteristics,' [he does] not regard the remainder

* Cope, Proc. Am. Ass. Adv. Sci., 19 meeting (1870), p. 226, 1871.

of the proposition and its corollary as necessary consequences of it."

I am happy to believe that there is only an apparent and no real difference between my eminent friend and myself, and that some misunderstanding has resulted on his part in an unconscious interpretation of the clause "affinities are only *determinable*," used in the proposition quoted, by something like the phrase "groups are only *diagnoscible*." I however deliberately used the former, and in the hope that my meaning might be clear, and not interpreted in the sense of the latter. I therefore reassert that the affinities of animals are only *determinable* by the sum of their agreements in *morphological* characteristics (and Professor Cope *in practice* adopts the principle), but freely assent to the proposition that natural groups *thus ascertained* may be *diagnoscible* by the expression of the modification of a single organ, and have acted upon it in the article quoted and in the present. And that Professor Cope has acted on the proposition that affinities are not "*determinable*" by the modifications of a single organ, but by their agreement in whole, is evident from his writings, and his practice in the article from which I have just quoted. For example, he there combines the *orders* of reptiles with "extremities differentiated" into major groups, primarily distinguished by the relations of the tubercular and capitular portions of the ribs.* Yet in the *order* of cetaceous mammals, he assigns a very inferior value to corresponding modifications of the articular surfaces of the ribs,† co-ordinating them with family characters. Now, there is no *à priori* reason that I am aware of, why these modifications should not be of as much taxonomic value in the one case as in the other. If, for example, we had only two reptiles, and two mammals, respectively exhibiting such differentiation as to the ribs among themselves, that differentiation having just originated, I know not what reason we would

* "Tubercular and capitular surfaces united," in SYNAPTOSAURIA, *i.e.* in *Lacertilia, Pythonomorpha,* and *Ophidia;* and in SYNAPTOSAURIA, *i.e. Rhynchocephalia, Testudinata,* and *Sauropterygia;* Tubercular and capitular surfaces separated; former on diapophysis, latter on centrum," in ARCHOSAURIA, *i.e. Anomodontia, Dinosauria, Crocodilia,* and *Ornithosauria.*

† "The hinder ribs losing their tubercle and retaining their capitular articulations with the vertebræ," in *Physeteridæ.* "The tubercular and capitular articulations of the ribs blending together posteriorly," in *Platanistidæ.* "Posterior ribs losing their capitular articulation, and only uniting with the transverse processes of the vertebræ by the tubercle," in *Delphinidæ.* — Cope, Proc. Acad. Nat. Sci., Phila., 1869, p. 20.

have to foresee a constantly increasing differentiation as to other points of structure in the one more than in the other. But as a matter of fact, we do see that there has been such differentiation in the reptiles (admitting, for the sake of argument at least, the naturalness of the associations sanctioned by Cope), and that co-ordinated with such characters are others which stamp them as "natural groups," while it is still more evident that in the case of the cetaceans, primary combinations distinguished by the rib-articulations would be solely based thereon, and that such modifications are not co-ordinate with others, and are therefore not indicative of true affinity. This has been fully recognized by Professor Cope; he has *determined* the affinities of the reptiles by an appreciation of their common agreements, has verified the constancy of the mode of articulations of the ribs, and their co-ordinations with other characteristics, and has therefore availed himself of the obvious characters furnished thereby for *diagnostic* purposes; on the other hand, he has appreciated the affinities *inter se* of the cetaceans, has verified the comparatively slight value of the mode of articulation of the ribs, and the absence of correlation with other characters, and has therefore properly limited the taxonomic value to family rank, and introduced them into the *diagnoses* of the families. In neither case, are the groups *made* simply because they are distinguished by their rib-articulations; they are *recognized* because of certain general agreements *inter se*, and the rib-articulations simply furnish good *technical* means for their further recognition and distinction. In practice, then, I repeat, there is no disagreement between us; and a proper distinction between the words *determinable* and *diagnoscible* would prevent any theoretical disagreement.

III.

The third proposition (respecting descent with modification) is too generally admitted by competent judges to need argument in this place.

IV.

A difficult problem is the arrangement, in a linear series, of forms so as to best express their relationships. This is perhaps most aptly effected by taking, in the first place, the most generalized type known (a), and follow that by the one (of two or more) most closely allied to it (a 1), then by the one nearest to that (a 2), and

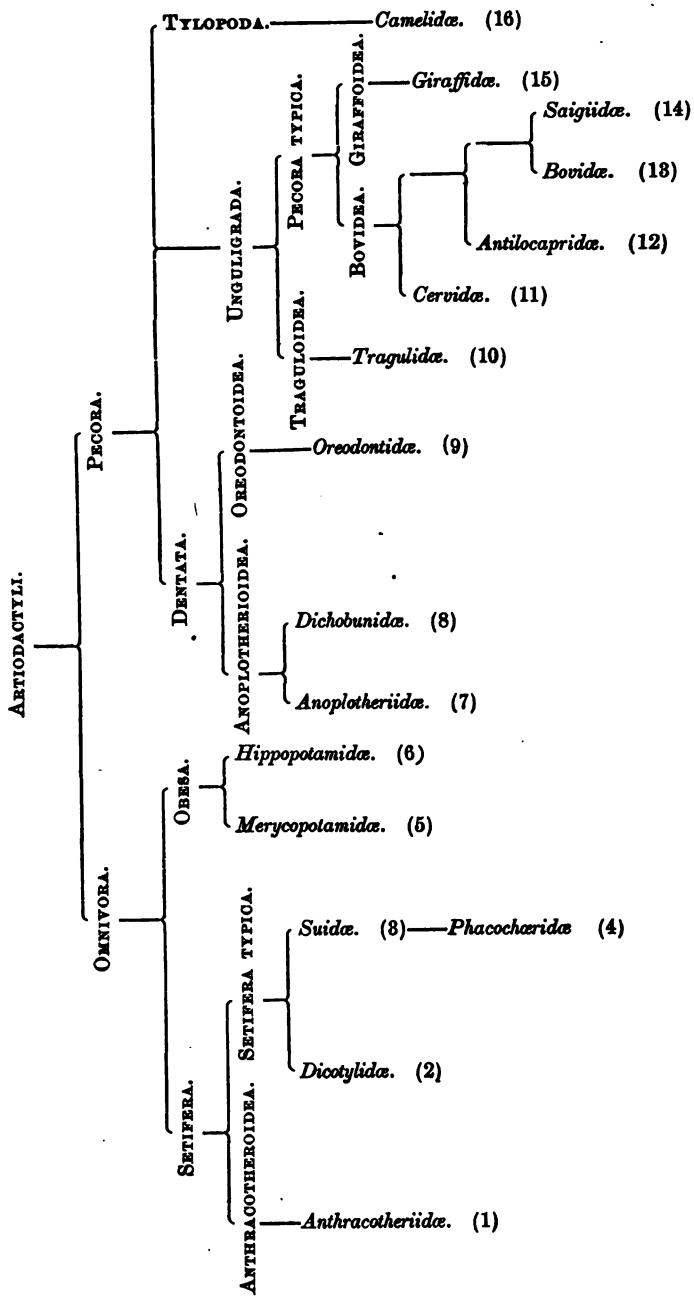
thus to the end of the series, wherever it may lead; then we may recommence with the one *next* most nearly related to (*a*) the first type, and project another series (*b*, *b*1, &c.). It will be evident that the last term of the first series (*ax*) will often be much less nearly related to the first term of its own series (*a*) than is the first term of the second series (*b*); and, of course, that it, — (*ax*) the last term of the first series, — so far from being intermediate between the two (*a* and *b*), must be the most remote from the first term, if we are right in the appreciation of the relative affinities* of the succeeding series, since both are the descendants of the same original progenitor. A more vivid appreciation of our meaning may be derived from an examination of the annexed table, and the succeeding exhibition in a linear series of its terms.†

In every case, the left branch of the fork (major as well as minor) represents the most generalized form, or, at least, that supposed to be the most generalized, and therefore the quasi-eldest. If, then, we commence with the most generalized forms, we must proceed from the left to the right, in the order indicated by the numbers inserted after the family names. But reference to the table will render it evident that there is nothing like a continuous series; and it is now removed beyond the province of doubt that such a phenomenon as the chain of beings, which existed in the imaginations of Lamarck and De Blainville, does not exist in nature; therefore, in no scheme can we interpose forms in a strictly linear series so as to exhibit their mutual affinities.

In most cases, in such a series, only the proximate affinities in one case can be exhibited. Thus, the family *Phacochœridæ*, in a linear series, is interposed between the *Suidæ* and the *Obesa;* but it is not intended to indicate that it is intermediate as to affinities, — far from it. It is the final and most specialized term of the series to which the former (with which it is most nearly related) belongs; and with the *Obesa* we commence a new series, which springs from the same common base, and apparently has its nearest relations among known types, with the *Anthracotheriidæ*. But to indicate

* In this respect, however, we must frequently expect to err; for, when called upon to express our opinion respecting the relative affinities and degree of generalization of three given forms, we may arrive at false conclusions from the paucity of material, as well as from attaching an undue importance to certain modifications.

† See Table on following page.


Artiodactyli.
Pecora.
Omnivora.
Tylopoda.
Camelidæ. (16)
Dentata.
Unguligrada.
Pecora typica.
Bovidea.
Giraffoidea.
Giraffidæ. (15)
Saigiidæ. (14)
Bovidæ. (13)
Antilocapridæ. (12)
Cervidæ. (11)
Traguloidea.
Tragulidæ. (10)
Oreodontoidea.
Oreodontidæ. (9)
Anoplotherioidea.
Dichobunidæ. (8)
Anoplotheriidæ. (7)
Obesa.
Hippopotamidæ. (6)
Merycopotamidæ. (5)
Setifera.
Setifera typica.
Suidæ. (3)—Phacochœridæ (4)
Dicotylidæ. (2)
Anthracotheroidea.
Anthracotheriidæ. (1)

SUBORDER ARTIODACTYLI.

OMNIVORA.

SETIFERA.

SUPERFAMILY ANTHRACOTHEROIDEA.

1 *Anthracotheriidæ.*

SUPERFAMILY SETIFERA.

2 *Dicotylidæ.*
3 *Suidæ.*
4 *Phacochœridæ.*

OBESA.

5 *Merycopotamidæ.*
6 *Hippopotamidæ.*

PECORA.

PECORA DENTATA.

SUPERFAMILY ANOPLOTHERIOIDEA.

7 *Anoplotheriidæ.*
8 *Dichobunidæ.*

SUPERFAMILY OREODONTOIDEA.

9 *Oreodontidæ.*

PECORA UNGULIGRADA.

SUPERFAMILY TRAGULOIDEA.

10 *Tragulidæ.*

SUPERFAMILY BOOIDEA.

11 *Cervidæ.*
12 *Antilocapridæ.*
13 *Bovidæ.*
14 *Saigiidæ.*

SUPERFAMILY GIRAFFOIDEA.

15 *Giraffidæ.*

PECORA TYLOPODA.

16 *Camelidæ.*

the termination of series, a new designation has been introduced, — the superfamily, — and it is to be understood that the second group originates either from the same common progenitor as the first, or from a representative of the first group. The serial exposition of the Artiodactyli will serve to illustrate the application of these principles.

The various relations and inter-relations of the families, or rather the views of the author respecting them, may be also ascertained by the braces connecting them; and it may not be superfluous to recall the statement that the affinities of the respective groups are apparent in the first or more generalized of each series, and that indeed it would be a matter, in the present state of our knowledge, of little moment whether we placed one or the other of two terms first, — whether, for example, we place the *Unguligrada*, or the family of camels, after the *Pecora dentata* (from some form of which it has probably been directly derived rather than from any of the specialized Unguligrade forms). For if, in some respects, the Unguligrades seem to furnish a less interrupted series from the *Pecora dentata*, the camels do in others. As, however, on the whole, the relations of the latter are less obvious, and as they exhibit several very specialized features, the present state of our knowledge seems better to be exhibited in the sequence adopted.

V.

In the appreciation of the value of groups, or at least those of ordinal rank, the views of Linnæus have been generally adopted by therologists as far as they could be consistently with the more advanced stage of knowledge, and an attempt, instinctive or avowed, has been made to apply the views which the great founder of systematic biology had vaguely conceived; the modifications have, however, been necessarily very great, and the groups which the intuitive genius of Linnæus perceived have only been rigorously defined, eliminated of heterogeneous elements, and correctly weighed as to relative value within recent times. It may be added that if the writer has especially introduced the proposition now explained in this article, it is only because some eminent and justly esteemed naturalists of this country have taken another view of the appreciation of the groups recognized by the father of the modern taxonomy.

Terminology.

In order to meet the exigencies of a taxonomic valuation of groups, the terms superorder and superfamily are introduced; their intended range may be best perceived by reference to their application in the present article.

Also, for the purpose of exhibiting in the descriptions, the *tendencies* as well as primitive characters of groups, and those characteristics which really materially influence the systematist in his conclusions, although he may not avail himself of them on account of their failure in universality, the terms archetypically, attypically, and etypically are used.

Archetypical characters are those which a group derives from its progenitor, and with which it commences, but which in much modified descendants are lost; such, for example, is the dental formula of the Educabilia ($M \frac{3}{3}$ $PM \frac{4}{4}$ $C \frac{1}{1}$ $I \frac{3}{3} \times 2$), — a formula, as shown by Owen, very prevalent among the early members of the group, but generally departed from more or less in those of the existing faunas.

Attypical characters are those to the acquisition of which, as a matter of fact, we find that forms, in their journey to a specialized condition, tend; thus, the Pecora or Ruminants have lost upper incisors, and this character seemed to entitle them, in the opinion of the early cultivators of zoölogy, to ordinal differentiation: we now recognize the comparatively slight value of the character, but itself and the tendency thereto are still significant, and influence, insensibly or openly, a more complete recognition of the group in part so characterized. Another example is furnished by the Solidungula, in which the specialized Equidæ formerly furnished the characters for the distinction of the group: the progress of discovery has, however, compelled a modification of diagnoses; but we are still influenced by the culmination of the characters distinctive of the horses, and it is proper to specify the tendencies thereto in a diagnostic form.

Etypical characters are exceptional ones, and which are exhibited by an eccentric offshoot from the common stock of a group. Such are the dental characters exhibited by certain Lemurids, the Aye-aye, &c.

Descriptive.

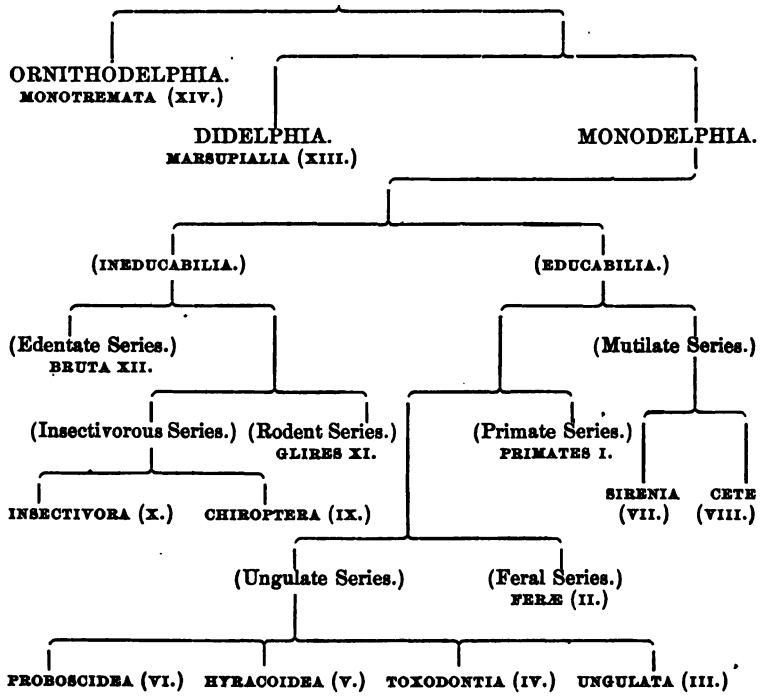
After the preceding introduction, the descriptions and reasons for combinations of the following groups may be more intelligible. The names in italics indicate extinct types.

The class of mammals is definable by the following characters, most of which have been especially exposed by Professor Huxley.

Mammalia.

Abranchiate Vertebrates with a brain whose cerebral hemispheres are more or less connected (and in nearly inverse ratio) by an anterior commissure, and a superior transverse commissure (corpus callosum); the latter more or less roofing in the ventricles. Skull with two condyles, chiefly developed on the exoccipital elements (one on each side of the foramen magnum): with the malleus and incus superadded as specialized auditory ossicles: and the lower jaw (composed of a pair of simple rami) articulated directly by convex condyles with the squamosal bones. Lungs and heart in the thorax, and separated from the abdominal viscera by a muscular diaphragm: aorta single and reflected over the left bronchus: blood with red nonnucleated blood-corpuscles undergoing a complete circulation; entirely received and transmitted by the right half of the quadrilocular heart to the lungs for aeration (and thus warmed), and afterwards returned by the other half through the system. Dermal appendages developed as hairs. Viviparous: young nourished after birth by a fluid (milk) secreted in peculiar glands (mammary) by the mother.

The relations of the several primary groups of the class may be more readily understood from a glance at the subjoined table, which will also serve as a genealogical table for those who accept the doctrine of evolution. The more generalized forms — and therefore the quasi-eldest — are represented by the left branches. It may not be entirely superfluous to remark that adaptive special modifications must be subordinated to morphological in every case: it will therefore be understood that although the Cetacean is, in a teleological sense, the most specialized form of mammals, it is a divergent from the same common stock as the Carnivores and other Educabilia, and must be contrasted morphologically with them alone and not with the rest of the mammals; the bat, another extremely specialized form, is in like manner a derivative from the same common stock as the Insectivores, and therefore to be contrasted with them alone.



Sub-Class Monodelphia.

Brain with the cerebral hemispheres connected by a more or less well-developed corpus callosum composed of a body as well as a folded psalterial portion, and a reduced anterior commissure; with a well-developed septum. Sternum with no element in front of the manubrium or presternum. Coracoid not connected with the sternum, but early anchylosed with and developed as a simple process of the scapula. Testes variable in position, but the vasa deferentia open directly or indirectly into a distinct and complete urethra (and not into a cloacal cavity). Ureters discharge directly into the bladder the renal secretion, which thence passes into the urethra. Oviducts debouching into a single vagina. Mammary glands with well-developed nipples. Young retained within the womb till of considerable size and nearly perfect development, and deriving its nourishment from the mother through the intervention of a "placenta" (developed from the allantois) till birth. Scrotum never in front of penis.

Super-Order Educabilia.

Brain with a relatively large cerebrum, behind overlapping much or all of the cerebellum, and in front much or all of the olfactory lobes; corpus callosum (attypically) continued horizontally backwards to or beyond the vertical of the hippocampal sulcus, developing in front a well-defined recurved rostrum.

(*Educabilia Quadripedia.*)

Posterior members and pelvis well developed. Periotic and tympanic bones articulated with the squamosal: etypically free and otherwise modified (*e.g.*, *Tapiridæ*).

(*Primate Series.*)

I. Order Primates.

Brain with a calcarine sulcus, giving rise to a hippocampus minor within the posterior cornu (when present) of the ventricle. Members almost or entirely exserted outside of the common abdominal integument. Digits with corneous appendages developed as claws (*i.e.*, compressed) or, attypically, as nails (*i.e.*, depressed). First digit (great toe) of hind foot (pes) enlarged, opposable to the others (in man, resuming parallelism with them), always furnished with a nail. Clavicles completely developed. Teeth of three kinds (canines of second set exceptionally atrophied), all encased in enamel; molars rooted. Incisors four in each jaw: etypically, two — or all — in upper jaw suppressed. Placenta deciduate, discoidal.

Contains eight families, representing two sub-orders: Anthropoidea, with five families, and Lemuroidea with three families.

SUBORDER ANTHROPOIDEA.

Superfamily Bimana.

1 Hominidæ.

Superfamily Simiæ.

2 Simiidæ.
3 Cynopithecidæ.
4 Cebidæ.
5 Mididæ.

SUBORDER PROSIMIÆ.

Superfamily Lemuroidea.

6 Lemuridæ.
7 Tarsiidæ.

Superfamily Dantentonioidea.

8 Dantentoniidæ-Chiromyidæ.

(*Feral Series.*)

II. Order Feræ.

Brain with no calcarine sulcus. Legs with the proximal joints (humerus and femur) more or less enclosed in the common abdominal integument. Digits with corneous appendages developed as claws: first digit of hind foot attypically reduced or atrophied: etypically hypertrophied (*e.g.*, *Pinnipedia*). Clavicles none, or rudimentary. Teeth of three kinds, all encased in enamel: canines specialized and robust; molars attypically adapted for carnivorous diet, one ($\frac{P.m.4}{m.1}$) or more in each jaw being sectorial, generally followed by tubercular ones. Incisors archetypically six in each jaw, exceptionally two or more suppressed. Placenta deciduate, zonary. Scaphoid and lunar consolidated into one bone.

Contains nineteen families, representing two suborders: Carnivora or Fissipedia, with sixteen families, three of which are extinct, and Pinnipedia with three families.

SUBORDER FISSIPEDIA.

Superfamily Aeluroidea.

9	Felidæ.	12	Hyænidæ.
10	Cryptoproctidæ.	13	Viverridæ.
11	Protelidæ.	14	Eupleridæ.

Superfamily Cynoidea.

15 Canidæ.

Superfamily Arctoidea.

16	Mustelidæ.	19	Cercoleptidæ.
17	Ursidæ.	20	Procyonidæ.
18	Aeluridæ.	21	Bassaridídæ.

Fissipedia incertæ sedis.

22	*Simocyonidæ.*	24	*Hyænodontidæ.*
23	*Arctocyonidæ.*		

SUBORDER PINNIPEDIA.

(*Diverging Series.*)

Superfamily Phocoidea.

25	Otariidæ.	26	Phocidæ.

Superfamily Rosmaroidea.

27 Rosmaridæ.

(*Ungulate Series.*)

Brain with no calcarine sulcus. Legs with the proximal joints more or less enclosed in the common abdominal integuments. Digits with corneous appendages developed as hoofs. Clavicles

entirely absent. Teeth of three kinds (canines and incisors of second set exceptionally in part undeveloped), all encased in enamel: molars attypically with grinding surfaces. Scaphoid and lunar separate.

III. Order Ungulata.

Incisors (archetypically $\frac{6}{6}$: often, especially in the upper jaw, reduced in number or wholly suppressed: implanted by simple roots) with incisorial crowns. Feet with inferior (or, rather, posterior) surfaces with a hairy skin continuous with the rest of the integument: carpal bones in two interlocking rows; cuneiform narrow, and affording a diminished surface of attachment forwards for the ulna (which is retrorse beside the radius); unciform and lunar articulating with each other and interposed between the cuneiform and magnum: hind foot with the astragalus at its anterior portion scarcely deflected inwards, articulating more or less with the cuboid as well as navicular: toes (not more than four — d 2 to d 5 — completely developed) with terminal joints encased in thick hoofs. Placenta non-deciduate (diffuse or cotyledonary).

Contains twenty-nine families, representing two suborders; Artiodactyli, with nineteen families, of which eight are extinct, and Perissodactyli with ten families, of which seven are extinct.

SUBORDER ARTIODACTYLI.

PECORA.

Superfamily Chalicotherioidea.

27a *Chalicotheriidæ.*

Pecora tylopoda.

28 Camelidæ.

Pecora unguligrada.

Superfamily Giraffoidea.

29 Giraffidæ.

Superfamily Bovidea.

30 Saigiidæ. | 32 Antilocapridæ.
31 Bovidæ. | 33 Cervidæ.

Superfamily Traguloidea.

34 Tragulidæ.

Pecora unguligrada incertæ sedis.

35 *Siratheriidæ.* | 36 *Helladotheriidæ.*

Pecora dentata.

Superfamily Oreodontoidea.

37 *Oreodontidæ.*

Superfamily Anoplotherioidea.

38 *Anoplotheriidæ.* | 39 *Dichobunidæ.*

OMNIVORA.

SUPERFAMILY OBESA.

40 Hippopotamidæ. | 41 *Merycopotamidæ.*

SUPERFAMILY SETIFERA.

42 Phaochœridæ. | 44 Dicotylidæ.
43 Suidæ. |

SUPERFAMILY ANTHRACOTHERIOIDEA.

45 *Anthracotheriidæ.*

SUBORDER PERISSODACTYLI.

SUPERFAMILY SOLIDUNGULA.

46 Equidæ. | 47 *Anchitheriidæ.*

SUPERFAMILY RHINOCEROTOIDEA.

48 Rhinocerotidæ. | 49 *Macraucheniidæ.*
| 50 *Palæotheriidæ.*

SUPERFAMILY TAPIROIDEA.

51 Tapiridæ. | 52 *Lophiodontidæ.*

SUPERFAMILY PLIOLOPHOIDEA.

53 *Pliolophidæ.*

PERISSODACTYLI INCERTAE SEDIS.

54 *Elasmotheriidæ.* | 54a *Anchippodontidæ.*

IV. ORDER TOXODONTIA.

Incisors ($\frac{2}{2}$ or $\frac{1}{1}$, variable as to insertion), with incisorial crowns. Feet? carpal bones? hind foot with the astragalus at its anterior portion inclined obliquely inwards, articulating in front only with the navicular; (calcaneum with an extensive upwards surface for the articulation of the fibula, and with a large lateral process articulating in front with the astragalus. Molars of upper jaw, broad and extending into an externo-anterior angle; of lower jaw, narrow and continuous in a uniform row).

Contains two families, both of which are extinct.

55 *Nesodontidæ.* | 56 *Toxodontidæ.*

V. ORDER HYRACOIDEA.

Incisors ($\frac{1}{1}$) of upper jaw next to symphysis (with persistent pulps) long and curved; those of lower jaw straight and normal. Feet with inferior surfaces furnished with pads (as in Rodents and Carnivores): carpal bones in two interlocking rows: cuneiform extending inwards (and articulating with magnum), and affording an enlarged surface of attachment forwards for the ulna (which is antrorsely twisted); unciform and lunar separated by the interposition of the cuneiform and magnum: hind foot with the astragalus

at its anterior portion extended, and, as a whole, much deflected inwards, articulating in front only with the navicular; toes (four to the front feet, three to the hind) with terminal phalanges encased in hoofs (inner nail of hind foot curved). Placenta deciduate, zonary.

Contains one family.

57 Hyracidæ.

VI. Order Proboscidea.

Incisors ($\frac{2}{0}$, or, in extinct forms, $\frac{2}{1}$ or $\frac{2}{2}$, renewed from persistent pulps), developed as long tusks curved outwards. Feet with palmar and plantar surfaces invested in extended pad-like integuments, which also underlie the toes: carpal bones in two regular (not interlocking) rows, broad and short; cuneiform extended inwards, broad, and furnishing an enlarged surface of attachment forwards for the ulna (which is antrorsely produced). Unciform directly in front of cuneiform, and magnum directly in front of lunar: hind foot with the astragalus at its anterior portion very short (convex), and not deflected inwards, articulating in front only with the navicular: toes (five to each foot, in known forms), encased in broad shallow hoofs. Placenta deciduate, zonary. (Snout produced into a very long proboscis. Legs mostly exserted outside the abdominal integument; and with the proximal and succeeding joints extensible in the same line.)

Contains two families, one of which is extinct.

58 Elephantidæ | 59 *Dinotheriidæ.*

(*Diverging Series.*)

(*Educabilia Mutilata.*)

(*Mutilate Series.*)

Posterior members and pelvis more or less completely atrophied; the form of the body being fish-like, furnished with a horizontal tail, and specialized for progression in the water. Periotic and tympanic bones anchylosed together, but not with the squamosal.

VII. Order Sirenia.

Brain narrow. Skull with the foramen magnum posterior, directed somewhat downwards: supra-occipital nearly vertical and not extending forwards, the parietals meeting and interposed be-

tween it and the frontal. Periotic with a posterior irregularly rounded part; tympanic annuliform. Lower jaw with well-developed ascending rami and normal transverse condyles and coronoid processes. Lateral teeth molar, and adapted to trituration of herbage. Neck moderate; second cervical vertebra with an odontoid process. Anterior members moderately long, flexed at the elbow; with carpal bones and phalanges directly articulated with the adjoining ones; and with normal digits. Mammæ two, pectoral. (Heart deeply fissured between the ventricles.)

Contains four families, one of which is certainly, and another probably, extinct.

SUPERFAMILY HALICOROIDEA.

60 *Halitheriidæ.* | 62 Rhytinidæ.
61 Halicoridæ. |

SUPERFAMILY TRICHECHOIDEA.

63 Trichechidæ-Manatidæ.

VIII. ORDER CETE.

Brain broad. Skull with the foramen magnum entirely posterior, directed somewhat upwards: supra-occipital very large, sloping forwards, and (attypically) extending forwards over or between the frontals. Periotic attenuated backwards; tympanic solid, entire. Lower jaw with no ascending ramus, with its narrow condyles at the posterior extremities or angles of the rami, and with only rudimentary coronoid processes. Teeth (lateral) conic or compressed. Neck attypically very short; second cervical vertebra with no odontoid process. Anterior members (attypically) abbreviated, extended backwards in a continuous line; with carpal bones and phalanges often separated by cartilage; and with the second digit composed of more than three phalanges. Mammæ two, inguinal.

Contains ten families, representing three suborders; ZEUGLODONTIA with two families, both extinct; DENTICETE with six families, one of which is extinct; and MYSTICETE with two families.

SUBORDER ZEUGLODONTIA.

64 *Basilosauridæ.* | 65 *Cynorcidæ.*

SUBORDER DENTICETE.

SUPERFAMILY DELPHINOIDEA.

66 Platanistidæ. | 68 Delphinidæ.
67 Iniidæ. | 69 Ziphiidæ.

SUPERFAMILY PHYSETEROIDEA.

70 Physeteridæ.

SUPERFAMILY RHABDOSTEOIDEA.

71 *Rhabdosteidæ.*

SUBORDER MYSTICETE.

72 Balænopteridæ. | 73 Balænidæ.

Superorder Ineducabilia.

Brain with a relatively small cerebrum, leaving behind much of the cerebellum exposed, and in front much of the olfactory lobes: corpus callosum extending more or less obliquely upwards and terminating before the vertical of the hippocampal sulcus, with no well-defined rostrum in front.

(*Insectivorous Series.*)

Teeth encased in enamel: incisors (very variable as to number) without persistent pulps: canines present (but sometimes modified in form): molars attypically with pointed cusps. Lower jaw with condyles transverse, received into special glenoid sockets. Placenta discoidal deciduate.

IX. ORDER CHIROPTERA.

Anterior members adapted for flight: the ulna and radius being united, and the metacarpal bones and phalanges — second to fifth — much elongated; the whole sustaining a very thin leathery skin arising from the sides of the body, and extending backwards on the hind members, down to their tarsi. (Mammæ pectoral).

Contains nine families, representing two suborders; FRUGIVORA with one family, and ANIMALIVORA with eight families.

SUBORDER ANIMALIVORA.

SUPERFAMILY DESMODOIDEA.

74 Desmodidæ.

SUPERFAMILY VESPERTILIONOIDEA.

75 Phyllostomidæ.
76 Mormopidæ.
77 Rhinolophidæ.
78 Megadermidæ.
79 Vespertilionidæ.
80 Molossidæ.
81 Noctilionidæ.

SUBORDER FRUGIVORA.

82 Pteropodidæ.

X. Order Insectivora.

Anterior as well as posterior members adapted more or less for progression on land: the ulna and radius entirely or partly separated: metacarpal bones and phalanges normally developed. (Mammæ abdominal: etypically—in Dermoptera, &c.— pectoral).

Contains ten families referable to two suborders; Dermaptera, with one family, and *Insectivora vera*, with nine families, one of which is extinct.

SUBORDER DERMOPTERA.

83 Galeopithecidæ.

SUBORDER INSECTIVORA VERA.

Superfamily Soricoidea.

84 Talpidæ. | 85 Soricidæ.

Superfamily Erinaceoidea.

86 Erinaceidæ.

Superfamily Centetoidea.

87 Centetidæ. | 88 Potamogalidæ.

Superfamily Chrysochloridoidea.

89 Chrysochloridida.

Superfamily Macroscelidoidea.

90 Macroscelididæ. | 91 Tupayidæ.

Insectivora incertæ sedis.

92 *Leptictidæ*.

(*Rodent Series.*)

XI. Order Glires.

Teeth encased in enamel: incisors ($\frac{2}{2}$; exceptionally, also two supplementary posterior teeth) continually reproduced from persistent pulps, and growing in a circular direction: canines null: molars attypically with ridged surfaces. Lower jaw with condyles longitudinal, and not received in special glenoid cavities, but gliding freely backwards and forwards. Members and feet ambulatorial. Placenta discoidal deciduate.

Contains sixteen families, representing two suborders: Simplicidentati, with fourteen families, and Duplicidentati, with two families.

SUBORDER SIMPLICIDENTATI.

Superfamily Lophiomyoidea.

93 Lophiomyidæ.

(*Carpophaga.*)

124 Tarsipedidæ. | 127 *Diprotodontidæ.*
125 Phalangistidæ. | 128 *Thylacoleonidæ.*
126 Phascolarctidæ. |

(*Entomophaga.*)

129 Peramelidæ.

SUBORDER DASYUROMORPHIA.

130 Dasyuridæ. | 131 Myrmecobiidæ.

SUBORDER DIDELPHIMORPHIA.

132 Didelphididæ.

MARSUPIALIA INCERTÆ SEDIS.

133 *Plogiaulacidæ.* | 134 *Dromotheriidæ.*

Subclass Ornithodelphia.

Brain with the cerebral hemispheres chiefly connected by a well-developed anterior commissure, the corpus callosum being very rudimentary, and with no defined psalterial fibres; with the septum very much reduced in size. (Flower.) Sternum with a peculiar T-shaped bone (the episternum or interclavicle) in advance of the manubrium or presternum. Coracoid extending from the clavicle to the sternum, and only towards maturity anchylosed with the scapula. The oviducts, enlarged below into uterine pouches, but opening separately from one another (as in oviparous vertebrates), debouch, not into a distinct vagina, but into a cloacal chamber, common to the urinary and genital products, and to the fæces. Testes abdominal in position throughout life, and the vasa deferentia open into the cloaca, and not into a distinct urethral passage. Ureters pour the renal secretion, not into the bladder, which is connected with the upper extremity of the cloaca, but into the latter cavity itself. Mammary glands with no distinct nipples. (Huxley.)

XIV. ORDER MONOTREMATA.

Only order of the subclass. Contains two families.

135 Tachyglossidæ. | 136 Ornithorhynchidæ.

4. NUMERIC RELATIONS OF THE VERTEBRATE SYSTEM. — By T. C. HILGARD of St. Louis, Missouri.

THERE are five (not four only) complete neural arches to the cranium of all vertebrate animals, to wit: (1) The condylar or sensitive belt with the condyle plates for side ribs and the lower arch of the *transversely bipartite* occiput for its vault pieces; (2) the petrosal or *acoustic*, containing the auditory nerves in its side beams (easily detected by removing the ear drum of Felines, &c.), and overarched by the anterior belt of the occipital squama; (3) the parietal belt originally containing the true gustative nerve of fixed tastes (sour, sweet, salt, and bitter, the glosso-pharyngeal), in an incision; from which it is, however, soon crowded out by the internal carotid artery and the overlapping "acoustic rib blade." The next (4) is the optic or frontal, visibly succeeded, in fishes, by (5) the ethmoidal or olfactory vertebra. The rest of the cranium is formed by its "extremities" or prehensile appendages.

The same numeric law which pervades the entire vegetable kingdom reoccurs in the human fabric in a very marked manner.

The number of "radiating elements" in a coil or whorl, or of whorls in a cycle, or in cycles generally speaking, as in pine cones and flower buds, &c., are the following:

1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, &c., progressing by the summation of the last two numbers.

The bands or parallel coils of flowers or scales in pine cones, sunflower discs, &c., embody these numbers successively, as they grow steeper and steeper, alternately on the right and left. The vertical bands, or columns, give the number of radial organs involved in each cycle.

The explanation heretofore given by me is this, that one element generates the other.

The elements are radial; they are bilateral rays, with a rift, so to speak, on the opposite side. It is there, where, in a like manner as the seed-leaves of flowering plants produce prolific "ovules," new radial organs are developed from the preceding ones, — laterally at alternate heights and toward the wider spaces.

This process, referred to the radial organs of plants in an early stage, will yield: —

1. The *numbers* of parts in question, successively.

2. The peculiar law of *interpolations* or of "divergence; viz., by a number of interstices represented by the second preceding one of each cyclar number.

3. It will *conclude* the cycles, if it be supposed that the activity of each junior member depends on that of its progenital one; as in all cases of simple branch developments.

These numbers occur in like manner in the human frame, as follows:

Inclusive of the terminal (ossified or gristly) coccygeal element, we have exactly thirty-four spinal vertebræ.*

Classifying nerves by their *work*, or "function," we find —

3 pairs of cervical nerves (neck).

5 pairs of bracchial nerves (arms).

8 pairs of pedal nerves, composed of 3 crural (lumbar) and 5 ischiadic (sacral) ones.

13 pairs of nerves to the rump.

5 specific ones of the cranium —

34 in all; whereas the number of the spinal vertebræ, which inclose the spinal cord, is exactly 21.

There are five pairs of "extremities," organized after a common plan: (1) the lower, (2) the upper, (3) the temporal (bearing the lower jaw for a "member"), (4) the palate-facial, with the upper jaw for its "member," (5) the opercular or hyo-tympanic one, forming the gill-lid in fishes or the tympanic ossicles in man; and the digital extremity of which is gradually converted into the (hand-like) crimped (external and internal) cartilages of the ear.

The five pair of hæmal arches of the cranium, *i.e.*, the gill arches of fishes, are gradually transformed into the gristles of the gullet, &c.

The main variation consists in the varying but "cyclar" number of "rays," — fingers, &c.; the varying cyclar number of their joints (1, 2, 5, 8, 13 respectively, in a dolphin, with five carpals, instead of eight, as in man) and the varying cyclar number of "loose" ossicles, such as *carpals*, *tarsals*, *teeth*, &c. The number of spinal vertebræ is also variable, but not that of the cranial ones.

The vertebral blocks, as well as the ribs, are the product of the primitive axial series of (intervertebral) discs, each of which, when completely arrayed, bears five branches; viz., two pair of hæmal arches, two pair of neural arches, and a fascicle of parallel cleets,

* The "epistrophean *tooth*" belongs to the *cranial* system.

so to speak, which being *cemented* together, both in front and rear, by the superficial ossification of the discs at either end, are fused into the block pieces, as found, *e.g.*, in the young hog; the cementing slab covering the big neural rib head likewise, and not only the pentagonal prismatic block. The first disciform ossification we find in the corals, forming cribrose ethmoidal discs, such as the closely set "sigillate impressions" of the Astræa, and afterwards left behind as the coccyx, *e.g.*, of Cyathophyllum.

In the crustaceans, we find each member composed of a corresponding number of radii; viz., the muscles, externally indurated (like nails, hoofs, and the shells of mollusks). In the joints of the lobster we find a commencement of central ossification indicated.

The numeric genesis requires a radiating bilateral organ to *start* on. *Self-repetition* engenders the spiral coil around an imaginary axis. The radiate type thence results. It is observed in fungi, in the toadstool's psaltered leaves, and in the ground-star. It is emphatically the type of the *moss*, and of all *buds* in general. In fruits and flowers the axial extension disappears almost entirely.

Flowers are essentially *radiate* organizations. So are the *viscera* of all animals, from the lowest Radiata to the highest Vertebrata. The organs of fructification are the only points of departure for a comparison between the two kingdoms.

Floral stratification is fivefold: (1) the calycine, (2) the lymphatic-erectile or floral cycle proper, *i.e.*, the petals, (3) the generative cell, or pollinary anther, (4) the pod-leaves, (5) the seed. The pod is crowned with a fringed stigma, which receives and conducts the loose produce of the anther. A thin cross-section of the apple exhibits this fivefold stratification in a carnified condition. The projecting angles are here derived from the second or lymphatic-petaliferous series. The flat sides terminate into the calycine lobes of the coronet. The intercapsular bolsters are due to the third or antheric series of the apple-flower.

Correspondingly, all the animal generative viscera — and again, conformably, the assimilative ones — are composed: (1) of the *cutaneous* lobes or "visceral arches" — misinterpreted for "hæmal rib-arches" (by a faulty comparison with *gill-arches**); (2) the *erectile* mucous layers, (3) the *glandular* series, (4) the *utricular*, (5) the *embryonic*.

* In the Fishes, both the "visceral" *and* the "gill"-arches are at once present.

The pelvic or generative viscera accord with the prevalent number of monocotyledons, 3 or twice 3 (= 6). There are three "utricular" organs, centring on the same point: the (mesial) bladder and (conjugate pair of) seminal (uterine) horns or vesicles. In likeness of a capsule, each is crowned with a suction-hose in analogy to the stigma of the vegetable generative apparatus. The bladder, in its original condition, is crowned with the placentary sponge; the uterine horns with the fringed *tubæ* (the male *epididymis*). Each has its corresponding gland, *i.e.*, a mass of conglobated cells, of specific functions: the bladder joins the *liver* by the open *urachus* — subsequently the "round" liver-ligament; the uterine horns join their respective glands — the "*ovaria*" *proper* — by their tubæ. Two kidneys send their channelled pedicels — the ureters converging to the same central spot, — alternating with the others. The spleen originally obtains the anterior position, but is crowded out, as the "animal leaf" closes up in front.

The testes, it is well known, in animal embryology are at first identical with the female ovaries; and *both are the true homologues of the anther* of flowers. The seminal vesicles, and correspondingly the uterine horns (the bladder), are the homologues of the (*utricular*) *pod-leaves*.

It is clear that the reception of the pollen is strictly homologous, thus far, with the conception of the female "ovum" at each period of menstruation. In a like manner, the *male receives the seminal cells into the seminal utricles*. A difference obtains in this, that the flower directly matures its own conception as a single glandular educt; whereas all animals, even the "hermaphrodite" snails (which secrete *both the semen and the ovum from one identical gland*) *require two different kinds of secretions, — a yolk and a semen, — both from homologous organs*. This double nature of the ovarian and testicular gland constitutes *sexual diversity* or *bi*-sexual generation. Flowering plants, therefore, have only a *uni*-sexual generation; *i.e.*, no sexual difference at all.*

In every case of comparison, the comparison must be true, *i.e.*, consistent. Our present sexual nomenclature and interpretation of floral parts is hence a foregone conclusion, based on erroneous ideas of animal forms and functions.

All these organs originally centre in the cloaca or tubular *rectum* (*colon*): the muscular bars or "striæ" whereof issue into the utero-

* Proceedings, 1871, p. 326, foot-note.

vesical muscular sheets. Its vascular plexus continue into the *erectile* or "cavernous" bodies. The internal or *glandular* stratum of the intestine is diffuse. It probably represents the (missing) sixth gland, if the spleen be apportioned to the fetal liver.

The upper or assimilative viscera of animals likewise conform to this type. There are the five "visceral lobes," — *no* "hæmal arches" proper,— the frontal, buccal and mammal ones; alternating with as many mucous membranes: the conjunctival, the tympanic and the lingual (oral); all meeting at the fauces-tympanic ducts, lachrymal ones (cloacal), and the throat or buccal cavity. Each is provided with a set of introverted glands, — the lachrymal, tonsils, and the lungs, respectively; while the cutaneous lobes (or so-called visceral arches) contain, — (1) the frontal one, the brains; (2) the two buccal ones, the parotids; (3) the mammal ones, the mammarian glands; five conglobations of *punctiform cell-tissues* of "specific" functions, as with all glandular bodies in general.

In Vertebrates, the reflexed frontal lobe becomes the domineering ray, forming the entire *embryonic hiatus*, or neural archway from the nose-tip to the coccyx. In its entire length, it cleaves to the disciformly dissected spinal column and all its osseous appendages, and thus by suturing its own borders, it is well-known, envelops the rest of the *truly radiate, visceral* fabric.

In the star-fishes, the "cutaneous" lobes are *intracted* — (as in the apple), *i.e.*, the seams bulged out into "rays" by the mucous system of entrails, alternate to its crown-lobes, — the rays being formed of two opposite borders. Each of these borders — as with the "animal leaf" of vertebrate animals — bears a compact marginal series of *fivefold* ossification of primitive nuclei: (1) a "*head*" or prop, (2) a "*blade*" or main lever, (3) an "*angulus*" or sidewise crank: the "transverse process," so called, (4) an *arch*, and (5) a *sternal* ossicle, meeting its partner from the other side. It is thus the biseriate "sternal plates" of Radiata, as well as the true "sternum" of Vertebrates, are formed. In cases of *ectopia cordis*, the sternal series remain thus far separate even in man. Calves grown together frontwise bear two sternums, one on each side, either of them formed from two opposite individuals, *meeting by halves.*

Both the "hæmal" and the "neural" visceral archways of vertebrata are supported by similar beams, meeting from either side. Each has (1) a head or prop, (2) a blade, (3) a transverse process, (4) an arch or "spine," and (5) a sternal — when complete.

In birds, these parts are seen sufficiently distinct and to perfection. In fishes, all the nuclei are mostly separate. The rib-heads (square in the herring) bear the spiniform blades, and often the transversals, and are oppressed, inserted, or transversely soldered upon the vertebral "blocks." The latter are hour-glass shaped in fishes, but pentagonal prismatic with the higher animals. In the young hog, &c., they still separate from the heavy block-shaped dorsal (neural) "rib"-heads, but afterwards get cemented together by a peripheric ossification — fore and rearward — of the primitive *intervertebral discs*. It is thus that the "corpus" of each vertebra is formed of at least three parallel central cleets; viz., the prismatic part enclosed between two neural rib-heads, and the two terminal slabs.

The gill-arches are formed like true ribs, but in the higher animals, it is well known, they become transformed into the gristly supports of the (introverted) respiratory gland, — or lungs and the larynx. In the cat, first it resembles the carapace of a turtle. The rib-"heads" are of the shape as of a *clavicle*. The "blades" are broad and leaf-like, joining closely (although not suturing, as in the cranium of vertebrate animals in general, and in the turtle-carapace). The "*transverse*" process is lodged backward in either; joining the neural spine, in the turtle. In other animals the end of the rib-blade itself invariably joining the "head or prop") *at an angle*, projects as the "tuberculum costæ." In the turtle, the sejunct "angulus" or third element joins the spine. The arch-pieces (or "spinal" processes, so-called) in the turtles form the tabulate border-seam of the carapace, similar to those of the catfish gill-arches; and the enlarged (and partly sejunct) *sternals form the lower shield of turtles*, as they form the "sternum" of birds, likewise.

The five pairs of "extremities" offer similar relations. Each complete pelvis consists, beside the sacral or vertebral part, on either side of *five* distinct bones: (1) an "ischium," (2) an "ileum," (3) an "os pubis" (transversal), (4) a *separate* "tuberositas ischii" (young dog, &c.,) and (5) a *separate* "crista ilei." Conformably, each complete shoulder, likewise consists: (1) of a *clavicle*, propping the shoulder-joint by its abutment against the sternum; (2) a shoulder-*blade;* (3) a coracoid or "crank" (*transversal*); (4) a "spina scapulæ;" and (5) a separate marginal cartilage when ossified, visibly sutured or jointed to the border of the blade.

In moles, the clavicle becomes an *anvil*-shaped block, abutting

on the keel-shaped sternum, as in birds. In birds, the strong, anvil-shaped shoulder prop is the true clavicle. The "furcular" bones hardly touch the sternum, and can only be identified with the coracoid. The rest remain gelatinous. In fishes, the shoulders form a ring. The anvil-shaped or skate-like bone, resembling strictly an ischium,* is the *true* clavicle of fishes. The strong "blades" pass it, and meet underneath the gullet by their ends or "tuberculum" (as of *ribs*). The *fourth* ("spinal") and *fifth* (apical) ossicle here follow in linear succession; as with the ribs, or the "long" bones (humerus, femur) either, being drawn out in an axial sense. As for the pelvic bones, the 4th element (or tuberositas ischii) cleaves to the 1st, from which it is supposed to have sprung, by dint of numeric genesis; while the 5th (or "crista ilei") clings to the 2d (its lawful "progenitorial nucleus").

In mammals, as in fishes, the temporal attachments, readily identified, *e.g.*, in the cyprinoid skull (buffalo-fish), and inserted into the cranium as in mammals, consists: (1) of an anvil-shaped (swallow-tailed) "meatus osseus;" (2) a temporal blade, or "squama;" (3) a posterior crank, or "mastoid," — its "transverse process" (whereon the shoulder-ring of fishes hangs); (4) a postern intercalary (or "tuberositas" as of the ischium) of the meatus-bone; (5) a zygomatic intercalary. In these fishes, the temporal attachments bear the closest resemblance to a mammal pelvis.

In all mammals, the lower jaw swings on the temporal supports, completing this, the *masseteric* extremity.

That the gill-lids, or opercular bones, of fishes are the *tympanic* bones of mammals, is acknowledged in their nomenclature. Comparing the "incus" of a hog with the "tympanic pedicle" of a small buffalo-fish, affords a good starting point. It forms the abutments, *prop*, or "head" (1). The blade (2) is the opercular bone, or "malleus" (3). The transversal, "uncinate element" (or *stapes*) is agglutinated forward as a crooked or semi-lunar slab. Nos. (4) and (5) play the parts of a "spina scapulæ" and "marginal" on the malleus or opercle (as comparable to a shoulder-blade). They form the "false tympani" and "styloid" process respectively. The prehensile levers, immediately attached, are the "hyoid" bones, with the "opercular fin" for its *hand*, so to speak. In the cod-fish, this apparatus is drawn out into a slender shape, half-way between

* In the buffalo-fish it presents strikingly the form as of an ischium and *arcus pubis*.

that of a shoulder and a "rib," — as the comparison is, with reference to the first point of departure.

Remains the palate-facial extremity.

The "pterygoid" bones of mammals are readily identified occupying the same position at the base of the skull in birds, likewise.

Its type can be immediately paraphrased, by bending down the *wings* of the same bird-skeleton, so as to meet with the elbows at the sternal crest. On a smaller scale, the strong, external palatal *prop*, or anvil — the "lamina pterygordea externa" of the bird — again repeats the type of the (*true*) clavicle (shoulder-prop) of birds. It is the much renowned "os quadratum."

Follows the *internal pt. lamina* in the semblance of a humerus; the "ossa palatina" as the "radii;" the confluent *vomeric leaves — one from either side* — as the "ulnary" corresponding parts. By means of an uncinate process (the "hamulus" of mammals) the *zygomatic* "blade" is joined to this "palatal shoulder." In fishes, where exactly the same bones are found (removed from the skull base, fronting the opercle), the zygomatic blade or "preopercular" is crested, &c., like a true shoulder-blade. In both classes the palatal "prop," besides directly issuing into the palatal "extremity," so to speak, *bears the mandible* likewise, — which is dislodged, and only *suspended* from the temporal bones. In mammals, it swings on the zygomatic process, in many on the osseous "meatus;" in birds and fishes, on the "pterygoids."

In amphibia, both the strong (cleidoid) "*meatus*" *and* the (cleidoid) "*pter. ext.*" bear the mandible conjointly, being mutually agglutinated.

In fishes, the vomeral plates from either side remain *separate*, as supports of the oral vault which contains the gill-arches. In the pike, particularly, a five-fold system of *palatal digits*, so to speak, forms: (1) the intermaxillary stumps; (2) the long labial bones, or "antrum tuberositatis," being a two-jointed digit; (3) the alveolar beams; (4) the phalangoid series, or nasal "alæ," surrounding the orbit; (5) the "processus nasalis max. sup.," "os lachrymale," "nasale," &c. In fishes the palatal shoulder apparatus, bearing both the upper and (by displacement) the lower maxillaris, consists of a "pter. ext." with a ginglymus; backed by the true zygomatic (preopercle) and a wedge-shaped "hamulus." The entire opercular system is here intercalated between the *temporal bones* above, and the *palatal* ones below; all being expanded into a barrel-shaped vault for harboring the gill-arches.

It will at once be understood that the "petrosal *bone*," as an independent beam, is no prehensile attachment; but, *enclosing, as it does, the semicircular canals*, in all classes, fishes included, it is by no means a "posterior" supernumerary or third (*sic*) sphenoidal wing; but offering, as it does, all the characteristics of a rib-arch requires to be explained as the (*true*) "acoustic" neural arch-beam. Its "head," or *condyle*, is easily detected in all fœtal mammal skulls, and denuded by removing the compound "ear-drum" (the *superimposed* "mastoid" and "meatus osseus"!). It harbors the "cochlea." Its blade proper is the petrosal slab itself, prolonged as a "tubercle" into the exostoses, which afterward form the carotic channel, hiding its "condyle" from view. Its "uncinate process," or transverse hook, is the "processus vaginalis;" corresponding, in that quality, to the "processus jugularis" of the rearmost and truly *vital* (*sensitive; motor and pneumogastric*) *condylar* vertebra of the vertebrate skull.

Besides the original embryonic spinal *hiatus*, the fœtal skull shows the "squama occipitalis" to be octo-partite; representing as it does the 4th and 5th (apical) ossicles of *two pairs of neural arches*, — (1) the "motor" condylar and (2) the "acoustic."

Conclusions.

There being *no vacant vertebral blocks* left to account for, as to their "hæmal and neural arches," the five pairs of extremities *cannot be claimed as such.*

The "transversal processes" of each and all having been *accounted* for, there is no space left, to claim the prehensile levers as "their transverse processes"!

The "occipital squama" having been accounted for as an actually *octonary* bone, it can in no wise be construed as an "odd," single, and supernumerary "key-stone" (Owen).

The piscine *temporal* bones being found in exactly the same relative position as with all other vertebrate animals, they cannot be claimed as "transverse processes" of a deficient number ("four") of cranial arch-beams.

The transverse processes of each of the *five* neural arches having been located, the true temporals cannot be required to fill their place, — there being no vacancies to fill!

The second side-slab (from behind) of fishes containing the "semicircular canals," the former are no "sphenoidal alæ" by any

means; which, if so, would simply imply — what it is — *one vertebra more* to be accounted for.

In reptiles, the last neural arch and "block" of the spinal column proper is *slipped off*, and "its ambit filled with flesh." It is thus that the *atlas* is first formed. At the same time the first or *inter-condylar* block of the skull is likewise "slipped off," and now adheres to the second, or "epistrophean," spinal vertebra, — *vide* turtle, — where it forms the "*tooth* of the epistrophean."

It is from this peaked and *rifted* tooth that all fibrous tissues of the cranial cavity, its cavernous and other *sinus*, and consequently the primitive vessel of the *heart* itself, takes its central radiation. One pair of meningeal follicles issue into the cochleas; another, into the eye-balls and its muscles; the fifth propends as a filiform hook from the open "nares," or *choanæ*, as the embryonic heart-vein. All are vibratory or "pulsating" muscular organs.

It is thus clear that the heart and *assimilative visceral fabric — the great distinctive between all plants and animals* — arises from the central, primitive (so-called "intervertebræ), chondroid disks, or axial beadstring. It is here, indeed, where we have to look for the first origin of the *ossified disks themselves*, as with the Encrinites and Corals; as well as for the *inter-discordal, truly "vertebrate,"* axial ossifications.

It is thus in strict conformity with embryological facts, to state of the primitive Radiate, petrified into the solid lagoon-reefs of the Astraeæ or the gyrose Macondrina ("brain-coral"), that "its heart or core is hard as the "nether" or under-sea *millstone*, — which it actually bears *around its neck!* It may be likewise stated that it "forms a lagoon in the ocean, and its breath kindles charcoal," or *oxidizes carbon*, — as a breathing being, the *reef* or living "*rib*" of the sea should do.

I here refer to a highly graphic description contained in one of the *oldest* records of our race and its legendary science. Induration and ossification of radial elements take place both peripherically and centrally, and herein the main difference between the vertebrate and the lower animals can be traced.

Loose ossicles, whether of the skin, the teeth, or as found in abortive fœtal cysts, all alike partake of a radiating, *molar*-like or tooth-shaped development. It will suffice here to quote the resemblance between the cutaneous spines of the globe-fishes (Diodon, Tetraodon) and the shark's teeth, for example, — taking in all claws, nails, hoofs, and lobster's tweezers.

It is thus, no doubt, that an early and poetic perception conceived of "weaponed men," having arisen out of "dragons' teeth," —the shattered remains of sharks and saurians "sown broadcast"! "giants" of stone, sons of the ground we tread on. Arising from the deep, the denuded oceanic strata, thus rendering up their *dead*, are calling aloud from stones, so to speak, where all human speech and record ceases.

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4. Observations on the Systematic Relations of the Fishes. By Edward D. Cope, of Philadelphia, Pennsylvania.

I. Preliminary.

The system of fishes as at present adopted in this country is the result of the labors of many naturalists, but chiefly of Cuvier, Agassiz, Müller, and Gill. Without going into the history of the subject at present, it will be proper to point out the principal modifications of Cuvier's system, introduced by his three successors. The orders of Cuvier were the *Chondropterygii*, *Malacopterygii*, *Acanthopterygii*, *Plectognathi*, and *Lophobranchii*.

Professor Agassiz, under the name of *Placoids*, adopted the first division: the second he called the *Cycloids*, the third *Ctenoids*, and then created a fourth order under the name of *Ganoids*, which should embrace a portion of Cuvier's *Chondropterygii* (the sturgeons), a portion of the *Malacopterygii abdominales* (the bony gars, &c.), and the two last orders of Cuvier. Professor Müller following, with a still more complete anatomical investigation, especially into the soft parts, discerned three *subclasses* in Cuvier's *Chondropterygii*, which he named the *Leptocardii* (lancelet), *Dermopteri* (lamprey, &c.), and the *Selachii* (sharks, &c.). In the then recently discovered Lepidosiren he saw a fourth subclass, *Dipnoi*.

Having instituted an investigation of Agassiz's Ganoids, in an able memoir he purged it of the *Plectognath* and *Lophobranchiate* divisions, which are obviously not related to it. These with the *Malacopterygians* and *Acanthopterygians* he erected into a sixth

subclass, the *Teleostei*. This subclass, containing the greater part of existing fishes, embraced six orders; viz., *Acanthopteri* (Cuvier's *Acanthopterygians*), *Anacanthini* (new, for the Cod family, &c.), *Pharyngognathi* (new, for fishes with connate inferior pharyngeal bones), *Physostomi* (Malacopterygians of Cuvier, nearly), *Plectognathi*, and *Lophobranchii* of Cuvier. The great number of facts in the anatomy of fishes added by Müller constitute him the father of modern ichthyology.

Professor Gill, in 1861, adopted many of the divisions of Müller, and rejected some: others were newly proposed. But four subclasses were recognized; the *Dermopteri*, which includes also Müller's Leptocardii; the *Elasmobranchii*, equivalent to Müller's Selachii; the *Ganoidii*, including here Müller's Dipnoi, and the *Teleostei*. Six orders were attributed to the last subclass, which were quite different from those of Müller.

Subsequent to this publication, important contributions to the system have been made by Kner, Lutken, Gill, Huxley, &c., which will be noticed at the proper time.

The writer having been engaged in an examination of the osteology of the bony fishes, and general anatomical studies of the whole, has proposed to point out some further modifications of the received system, which he believes will render it a closer reflection of nature. There are some portions of the skeleton which have been to a great extent overlooked in seeking for indications of likeness and difference of types, and the estimation in which many known characters are held may be much altered on the study of extended material. The skeletons on which the present study is made are 1,000 in number, 200 belonging to the Academy of Natural Sciences of Philadelphia, and 800 to the writer, being the collection made by Professor Joseph Hyrtl, the distinguished anatomist of Vienna. This collection has been long known to anatomists in Europe as the most beautifully and reliably prepared in existence, and as valuable as any for study, on account of the fulness of the representation of the various types.

II. Special on the Ganoids.

Recurring to Müller's system, the writer adopts, as characterized beyond dispute, his sub-classes, or orders of Leptocardi, Dermopteri, Selachii, and Dipnoi, and confines himself at present to the recent *Ganoidea* and *Teleostei*. I have shared in the doubts occasionally expressed by icthyologists as to the essential distinc-

tion of these latter divisions, and an examination into the osteology with reference to this point confirms the doubts raised by a study of the soft parts. As is well known, Müller distinguished the Ganoidea by the muscular bulbus arteriosus containing numerous valves, and the connection of the optic nerves by commissure rather than by decussation. He added several other characters, knowing them, however, to be shared by various other orders and subclasses; and I have selected the only two which seemed to be restricted to the division. Their restriction to it, however, is only apparent; and Kner points out that the peculiarity of the optic commissure is shared by some *Physostomi*, and that the difference between the number, character of the valves of the bulbus in *Lepidosteus* and *Amia*, is quite as great as that existing between *Amia* and some of the *Physostomi*. After an examination of the skeleton it is obvious that in this part of the organism, also, there is nothing to distinguish this division from the *Teleostei* of Müller. It is true that each of the genera referred to it possesses marked skeletal peculiarities, but they are either not common to all of them, or are shared by some of the *Physostomi*. If, on the other hand, we compare these genera with each other, differences of the greatest importance are observable, which at once distinguish two divisions, one represented by *Polypterus*, the other by *Lepidosteus* and *Amia*.

In the first place the basal radii of the pectoral fins of *Polypterus* are observed to be excluded from articulation with the scapular arch by the intervention of three elements, which form a pedicel or veritable arm for the fin. In *Lepidosteus* and *Amia* the radii are sessile on the scapular arch as in ordinary fishes. The ventral fins present a like difference: the basal radii are long and four in number in *Polypterus*. In the other two genera they are absent, excepting one rudimental ossicle on the inner basis of the fin (two in *Lepidosteus*) precisely as in the Physostomous families, *Mormyridae*, *Catostomidae*, &c. If we examine the branchial apparatus, we find an undivided ceratohyal, three branchihyal arches, and no inner and but two outer bones of the superior brachihyals, present in *Polypterus*. In *Lepidosteus* and *Amia* we have the double ceratohyal, four branchihyal arches, with four outer and four inner superior elements, which are characters of the typical *Teleostei*. The maxillary bone of *Polypterus*, instead of being free distally, as in fishes generally, is united with an ectopterygoid, and with bones representing, in position at least, postorbital and malar. In the

other genera the relations of the maxillary are as in osseous fishes.

The sturgeons (*Accipenseridae*) agree with *Amia*, &c., in all of these points but one, differing only in having the superior ceratohyal and several of the superior branchihyals cartilaginous. The one point of distinction is the extension of the basal radial supports of the ventral fin all across its basis, as in *Polypterus*. The pectoral fin is, on the other hand, much as in *Lepidosteus*. Thus the sturgeons combine in this one respect the features of both divisions. Both the basal ceratohyals are cartilaginous in this family: the superior only is cartilaginous in *Polypterus*, *Lepidosteus*, and *Amia*, while both are ossified in the old *Teleostei*, except in the eels. In these the inferior is cartilaginous, while the superior is coössified to the ceratohyal. Thus in one unimportant character *Polypterus* agrees with its former associates, but differs more from others of them — the sturgeons — than from the bony fishes.

Another character of both *Lepidosteus* and *Amia* betoken a certain relationship to *Polypterus*; viz., the complexity of the mandible, especially in the possession of a coronoid bone. But here again *Accipenser* only possesses an osseous dentary, while *Gymnarchus* and *Gymnotus* have the angular and articular bones distinct from the dentary, wanting the coronoid and opercular. In most bony fishes the angular is not distinct.

It is thus evident the subclass Ganoidea cannot be maintained. It cannot be even regarded as an order, since I will show that *Lepidosteus*, *Accipenser*, and *Amia* are all representatives of distinct orders. I hope also to make it evident that *Polypterus* should be elevated to the rank of a subclass or division of equal rank with the rest of the fishes, and with the *Dipnoi* already adopted.

The question may then be discussed as to whether naturalists are correct who regard the fishes as representing variously from two to four classes. One of these (the Ganoidea) having been already disposed of, it remains to consider the claims of the remainder; viz., the *Elasmobranchii* (sharks), *Dipnoi*, and typical fishes.

If we examine the points in which the whole taken together differs from the *Batrachia* and other classes above it, we find that it is confined chiefly to the structure of the limbs and the hyoid apparatus. The typical fishes present, however, other important peculiarities; viz., 1st, The existence of two or three distinct bones in the suspensor of the mandible instead of one; 2d, The attach-

ment to these of the opercular bones; 3d, The absence of pelvic bones; 4th, The suspension of the scapular arch to the cranium; 5th, The large development of the pterotic (Parker, *Mastoid*, Cuvier and Owen) is characteristic of bony fishes.

The types of variation, in the first point, only distinguish groups of subordinate rank. Thus, the suspensor of the mandible in the typical fishes consists of the hyomandibular stapes, quadrate (metapterygoid or incus) symplectic and mesopterygoid (quadratojugal, Müller; quadrate, Huxley, Elm. Comp. Anat.). In the *Mormyridae*, *Siluridae*, *Polypteridae*, and others, the symplectic is absent: in the eels of several families both it and the metapterygoid are wanting, reducing the suspensorium to a rod of two pieces. This condition exists in many of the rays: in others, and in the sharks, the inferior element is wanting (Müller, Stannius). An important modification is exhibited by *Chimaera*, where the hyomandibular, which alone exists, is continuous with the cartilaginous cranium, not being separated by the usual articulation.

As to the opercular bones, all are wanting in the Elasmobranchs (sharks and rays); while the typical fishes possess four, — viz., preoperculum, operculum, suboperculum, and interoperculum. In many of these, however, the suboperculum is wanting, and in the sturgeons and many eels there is no preoperculum. In *Polyodon* the interoperculum is also wanting. In *Lepidosiren* the operculum and interoperculum are rudimental. In respect to this point also, the divisions indicated are of subordinate value.

As regards the development of the pterotic bone, its relations to the other bones forming the lateral walls of the cranium may be thus described.

In Polypterus the basioccipital is much prolonged posteriorly, and the exoccipitals are directed forwards in consequence. The basioccipital rises laterally to meet them at the vagal foramen. The exoccipitals are in contact, and the place of the supraoccipital is taken by cartilage. The outer suture of the exoccipitals extends obliquely backwards to the basioccipital. About half way along it, the suture dividing the epi- and opisthotic bones originates and runs forward into a fossa, which is roofed by the dermal ossification of the former. That bone has a long acute posterior prolongation. The opisthotic lies along side of it, and is overlaid by its dermo-ossification, having none of its own. It presents a process backwards parallel to that of the epiotic. The episthotic is a long bone, extending beneath the edge of the parietal, leaving a space

between it and the postfrontal. It subtends the long vagal foramen posteriorly with the exoccipital and basioccipital. With the latter, it bounds inferiorly the cartilage-covered space seen in *Amia Lepidosteus*, &c. The proötic is a small element, with a deep longitudinal groove on its outer face. It is bounded both above and below by projections of the opisthotic, and a tongue of the same enters a deep median longitudinal notch. A cartilaginous space separates it from a cup-shaped process of the parasphenoid below: in front it is connected with a transverse ala of the parasphenoid. I can find no separating suture. The latter supports above the lower extremity of the postfrontal. The parietals lie directly on the opisthotic without intervention of a pterotic. The hyomandibular abuts directly against the opisthotic. A bone is attached to its proximal end behind, and abuts with it. This is perhaps the preoperculum, and it bears a little dermo-ossified surface.* The groove of the proötic terminates in a foramen, which it partly encloses, past the ?parasphenoid. This probably gives exit to one of the branches of the fifth nerve. Two others exist anterior to it. The orbits are separated by the long ethmoid.

In *Lepidosteus* the basioccipital rises in two lateral plates behind the exoccipitals. The latter are in contact, and there is no supraoccipital. Epiotic prominent with a posterior and an interior face. Space for the opisthotic cartilaginous. The parasphenoid does not rise to meet the proötic, hence another cartilaginous space is enclosed by these two bones with the exoccipital. The proötic is a large bone, with a strong, concave-edged ala projected outwards and forwards, dividing a latero-inferior from a supero-anterior face. The latter is excavated for the exit of the 5th pair nerves. Its lower free edge is truncated transversely, and is continuous with a circular edge of an ala of the parasphenoid, the two bones forming a transverso-oblique plate. The free edge is obtusely rounded for articulation with the free concave extremity of the metapterygoid. The superior outer angle of the proötic supports a flattened conical postfrontal.

There is no true *pterotic*, but a dermo-ossification outside the parietals corresponds to it. There is an alisphenoid in front of the proötic, and an orbitosphenoid in front of this, which are united above, or separated by a very narrow fissure.

* In removing the hyomandibular, a margin of this preoperculum is apt to break off and adhere to the opisthotic, resembling a rudimental pterotic.

In *Amia* the opisthotic and epiotic are separated by a deep fossa. The opisthotic is separated from the parasphenoid by a cartilaginous space. The pterotic is developed as a narrow plate. It is bounded below by a large cartilaginous space, separating it from the proötic. Behind, it rests on the opisthotic. A supero-transverse process of the parasphenoid extends in front of the proötic and of the cartilaginous space in front of it, and supports the postfrontal. The alisphenoid is in front of this process, and in front of this an orbitosphenoid. No inter-orbital ethmoid. The dermal representative of the pterotic is well developed.

In *Accipenser* and *Polyodon* the pterotic is not ossified, and the opisthotic is probably also wanting.

With regard to the pterotic and opisthotic bones, then, there is as much difference between these so-called Ganoid genera as in other points. Especially is *Amia* separated from the others, and identified with the true bony fishes. But experience shows the differences in degree of ossification are of less weight than differences of original composition.

The Elasmobranchs are well known to have the scapular arch suspended freely behind the cranium as in higher vertebrates. It is not always attached to the cranium, on the other hand, among true fishes; for in the eels it is quite as in the sharks, and the spinous-finned *Mastacembelus* presents the same features.

The characters presented by the pelvic bones and limbs seem to be of higher imports. Thus all the bony fishes and sturgeons lack all the pelvic elements. In the sharks and rays they are also wanting; but two elements on each side appear in the *Holocephali* (Chimæra) according to Leydig and Gegenbauer. In *Lepidosiren* a large median pelvic cartilage exists, but which element it represents is unknown. This is evidently a character of high significance. As to the limbs, the peculiarities of *Polypterus* have been pointed out above. They mean nothing less than the development of the elements of the arm and leg of the higher vertebrata, which intervene between the point of articulation and the distal segments, in *Polypterus* and the sharks and rays. In the former the distal segments are articulated exclusively to the extremities of the proximal pieces, which thus resemble, as well as represent, humerus and femur, and render the limb pedunculated. The proximal pieces are not continued distally, however, into the representatives of the main axis, which, as demonstrated by the admirable studies of Gegenbauer, consist, after humerus, of radius, tarsals and meta-

tarsals, and thumb; in the hind limb, of the line of the tibia and inner toe. This continuation is observed in the *Elasmobranchii*, where, however, the divergent segments extend along the sides of the proximal pieces to near, in some *Rajidae* quite, to the articulation with the scapular arch. In the true fishes, including some of the old Ganoids already considered, the divergent rays always reach this articulation, while the number of proximal or basal pieces is diminished. These pieces have been called by Gegenbauer the metapterygium (humerus), mesopterygium, and propterygium; the first being axial, the second and third being divergent from it. In *Polypterus* the propterygium and mesopterygium are largely developed; in sharks and rays the propterygium is sometimes small, sometimes wanting; while in the true fishes the propterygium and mesopterygium are both wanting, excepting in *Amia*, *Lepidosteus*, and the sturgeons, where a cartilaginous mesopterygium exists, according to Gegenbauer. This author finds it rudimental in young *Salmonidae* and *Siluridae*. Lastly, in the true fishes the distal elements of the axis of the limb are wanting, just as in *Polypterus*.

In *Dipnoi*, on the other hand, we have this axis complete, or rather with greatly multiplied distal segments, and without lateral radii, except in the African *Protopterus*. Here Peters found a few attached to the proximal segments. Hence the limb in this order is termed by Owen the simplest or primary type, and this proposition is abundantly confirmed by the beautiful researches of Gegenbauer. The foundation for the history of the genesis of limbs laid by this author will ever be a landmark in the history of *modern theories of creation*. See his memoir, Ueber das Skelet der Gliedmaasen der Wirbelthiere im Allgemeinen, &c., *Jenaische Med. Zeitschr.*, vol. v. p. 397.

Important as are the characters that distinguish the several groups indicated by the different types of structure of the limbs and pelvis, they do not seem to me to warrant their recognition as classes, equivalent to those of the six already pointed out. Taking them together, there is a greater coherence also in the structure of brain and circulatory systems than would be the case with any other two of the classes adopted above. The peculiarities of the limbs, important as they are, are nearly related in the want of specialization of their parts, seen in the *Batrachia* and other classes, the differences consisting rather of number and position of parts. The pelvis of the *Dipnoi* might be regarded as of primary impor-

tance but for its existence in the *Holocephali*, whose limbs again are so near those of the shark.

It remains, therefore, to adopt the Linnæan and Cuvierian class *Pisces*, and to grant as such classes the groups of *Holocephali*, *Selachii*, and *Dipnoi*. There remain as subclasses the groups typified by *Polypterus* on the one hand, and the true fishes on the other. The first has been already distinguished in its external characters by Professor Huxley, who again brought light out of obscurity when he established his "third suborder of Ganoids, the *Crossopterygidae*." This division is in my estimation a natural one, and to be elevated to a rank equivalent to that of each of the three above named, being the only part of the original division of Ganoids of Müller entitled to it. Professor Huxley defined it as follows: —

"Dorsal fins two, or, if single, multiplied or very long; the pectoral and usually the vertical fins lobate; no branchiostegal rays, but two principal, with sometimes lateral and median jugular plates situated between the rami of the mandible; caudal fin diphycereal or heterocercal; scales cycloid or rhomboid, smooth or sculptured."

Of the above characters that which relates to the lobate fins is the essential one, and is the expression of the external appearance produced by the structure of the bones of the limbs already pointed out by Gegenbauer. Some of the genera included by Huxley with acute lobate fins, *e.g.*, *Phaneropleuron*, must however be referred to the *Dipnoi*, according to Günther. The absence of branchiostegal rays is important, but is shared by the sturgeons. The jugular plates appear to exist in Polypterus only among recent fishes, though several, as *Amia*, *Elops*, *Osteoglossum*, &c., possess a median one. Nevertheless, its nature would not lead one to anticipate its being a constant feature in any group of high rank; at least such is our usual experience with dermal bones. The structures of the skin and scales given by Huxley are very subordinate.

The remaining division answers then to the *Teleostei* and *Ganoidei* of Müller, minus *Polypterus*. The name *Teleostei* cannot be preserved for this division, owing to its entire want of coincidence with that division of Müller, as well as from the fact that the cartilaginous sturgeons must be included in it. I propose, therefore, to call it the *Actinopteri*. The characters of the five subclasses will then be as follows: —

Class Pisces.

The hyomandibular bone continuous with the cartilaginous cranium, with a rudimental opercular bone. Two distinct pelvic bones on each side. Derivative radii sessile on the sides of the basal bones of the limbs, separated from the articulation. *Holocephali.*

Hyomandibular bone articulated with the cranium; no opercular or pelvic bones. Derivative radii sessile on the sides of the basal bones of the limbs, rarely entering articulation. *Selachii.*

Hyomandibular bone articulated, with rudimental opercular bones; a median pelvic element. Limbs consisting of the axial line only, commencing with the metapterygium, and with multiplied segments. *Dipnoi.*

Hyomandibular articulated, opercular bones well developed, a single ceratohyal; no pelvic elements. Limbs having the derivative radii of the primary series on the extremity of the basal pieces, which are in the pectoral fin metapterygium, mesopterygium, and propterygium. *Crossopterygia.*

Opercular bones, well developed on separate and complex suspensorium; a double ceratohyal, no pelvic elements. Primary radii of fore limb parallel with basilar elements, both entering the articulation with scapular arch. Basilar elements reduced to metapterygium and very rarely mesopterygium. Primary radii of posterior limb generally reduced to one rudiment. *Actinopteri.*

III. On the Actinopteri.

In determining the primary types of this subclass, we return to some characters already mentioned, in which they approximate the *Crossopterygia*, and, adding others, follow the various divergences to their specialized terminations.

Thus, in *Accipenser* and allies, the ventral fins possess a complete series of basal radial bones, and the pectorals each a large mesopterygium. In *Amia* and *Lepidosteus* the mesopterygium is small, and the basal radii of the ventrals are reduced to their lowest number. In none of them are the basihyals fully developed. Most of the eels retain a character which we have only observed heretofore in the *Selachii.*

We pass by a number of the lower fishes before we find the mandibular arch furnished with a symplectic. One of the most important modifications, which is more or less coincident with a number of others, is that which formed the basis of Bonaparte and

Müller's order of *Physostomi*. The presence of the ductus pneumaticus which characterizes it is always associated with abdominal position of ventral fins and cycloid scales, and mostly with the presence of the præcoracoid arch, the entrance of the maxillary bone into the border of the mouth, and the non-separation of the parietal bones by the supraoccipital. Yet none of these characters are precisely associated at the point of change in each; for there are physostomous fishes with separated parietals and ctenoid scales (some *Cyprinodontidae*), and there are *Physoclysti* with abdominal ventrals. Nevertheless, three prominent types stand out in the *Actinopteri*, the sturgeons or *Chondrostei*, the *Physostomi*, and the *Physoclysti*, which may be considered as tribes.

An entire series of basilar segments of the abdominal ventral fins; no branchiostegal rays nor pterotic bone. *Chondrostei.*

Basilar segments of ventrals rudimental, position of fins abdominal, parietal bones usually united; branchiostegal rays; swim bladder connected with the stomach or œsophagus by a ductus pneumaticus. *Physostomi.*

No ductus pneumaticus; parietal bones separated by the supraoccipital; ventral fins usually thoracic or jugular; no basilar segments. *Physoclysti.*

Chondrostei.

There are two orders in this division, as follows: —

A præcoracoid arch; no symplectic bone; premaxillary forming mouth border; no suboperculum nor preoperculum; mesopterygium distinct; basihyals and superior ceratohyal not ossified; interclavicles present; no interoperculum or maxillary; branchihyals cartilaginous. 1. *Selachastomi*, — the Paddle-fish.

Similar to the last, but with interopercle maxillary bones, and osseous branchihyal. 2. *Glaniostomi*, — the Sturgeons.

The first order embraces the single family of *Spatulariidae*, the second that of the *Accipenseridae*. In both the chorda dorsalis persists, the tail is heterocercal and the osseous cranium is little developed. The basal and radial elements of the limbs, with the coracoids, are not ossified.

Physostomi.

The following key will express the leading features of the orders of this division.

I. A PRÆCORACOID ARCH.

A. A coronoid bone.

Maxillary in many pieces; vertebræ opisthocœlian. 3. *Ginglymodi*, — the Bony Gar.

Maxillary not transversely divided; vertebræ amphicœlian. 4. *Halecomorphi*, — the Dog Fish.

A A. No coronoid bone.

*No symplectic bone.

Pterotic simple, anterior vertebræ with ossicula auditus; supraoccipital and parietals coössified. 5. *Nematognathi*, — the Cat Fishes.

Pterotic annular including a cavity, closed by a special bone; parietals distinct, vertebræ simple. 6. *Scyphophori*, — the Mormyri.

**Symplectic present.

Anterior vertebra coössified and with ossicula auditus. 7. *Plectospondyli*, — the Suckers, &c.

Anterior vertebræ, similar distinct, without ossicula auditus. 8. *Isospondyli*, — Herring, &c.

II. NO PRÆCORACOID ARCH.

A. Scapular arch suspended to cranium.

B. A symplectic.

Pterotic and anterior vertebræ simple; parietal separated by supraoccipital. 9. *Haplomi*, — Pike, &c.

Anterior vertebræ modified; parietals united; pectoral fins. 10. *Glanencheli*, — Electric Eel.

B B. No symplectic.

Anterior vertebræ simple; a preopereulum and maxillary; no pectoral fins. 11. *Ichthyocephali*, — Java Eels.

A A. Scapular arch free behind the cranium.

*A preoperculum.

A symplectic; maxillary well developed; no pectoral fins. 12. *Holostomi*, (Symbranchi).

No symplectic; maxillary lost on connate; pectoral fins. 13. *Enchelycephali*, — Eels proper.

**Preoperculum wanting or rudimental.

No symplectic, maxillary, nor pectoral fins; no pterygoid. 14. *Colocephali* (Muraenae).

Of the above orders the *Haplomi* (pike, &c.) approach nearest the *Physoclysti* of the families *Opheocephalidae* and *Atherinidae*; and the *Holostomi* of the family *Symbranchidae* to the Physoclyst family of *Mastacembelidae*. The affinities between these families

are in both cases so close as to render the distinction of the primary divisions in question hardly worth preserving.

The complete development of the support of the caudal fin is seen in many members of this tribe, while in many of them it remains in its primitive condition. Among *Physoclysti* it is nearly always complete, though in a few (*Trichiuridae*, &c.) it remains larval. In the first development of the vertebral column in fishes, it forms a straight axis. The fin is represented by a fold of the integument which extends equally round its extremity. In this membrane the rays are developed, and in many fishes they remain thus equally distributed. In this case the caudal vertebræ remain in a straight line to the extremity, and we have a termination such as is seen in *Lepidosiren* and the eels. This form of tail may be called the *isocercal*.

If now the radii, basal or distal, acquire a greater development on the lower side of the column, those on the upper side remaining rudimental, it will be necessary that such enlarged portion should strike the water in the plane transverse to the longitudinal axis of the body, in order that the weight of the body be propelled with the least expenditure of force. This will necessarily cause the distal vertebræ, or end of the chorda dorsalis, to be turned upward, so that the inferior rays of the fin shall be brought as near to the line of the superior as possible. This is the type of tail known as the *heterocercal*, as called by Agassiz.

We find among the *Physoclysti* that the lower rays of the fin are more and more strengthened, and the hæmal spines, which support them, are more and more enlarged. Consequently the end of the column is more curved upwards, as seen in *Amia*. The superior rays and neural spines are also strengthened, and the inferior so extended upwards as to pass round the extremity of the column and come into contact with them. And now the vertebral centra are successively atrophied from the extremity. Counting from the extremity to the bases of the first supports of the outer rays of the caudal fin above and below, we find that ten vertebræ remain in the tail of *Notopterus*. In the *Hyodontidae*, *Albulidae*, *Elopidae*, *Alepocephalidae*, and *Salmonidae*, there are but two left, while one only appears in the *Osteoglossidae*, *Aulopidae*, *Lutodiridae*, *Butyrinidae*, *Coregonidae*, *Clupeidae*, and *Chirocentridae*. In most other families, especially of *Physoclysti*, the last one has disappeared, and the numerous hæmal arches are arranged like radii diverging upwards and downwards from the last caudal vertebra.

In the highest groups, as *Pharyngognathi*, &c., they become co-ossified; and the tail has completed its specialization. This is the type called *homocercal* or *diphycercal* by later writers.

These types are thus plainly stages in the development of this member, the first and second being simply arrests of development of the last. Thus the young salmon commences with an eel-like vertebral column, or is *isocercal:* it presently, by the upward curvature of the column, and unequal development of the caudal fin, becomes *diphycercal*, but ceases to grow before it has quite accomplished this stage. The *Polypterus*, the eels, *Gymnarchus*, and other fishes, ossify the vertebræ in the isocercal stage. The heterocercal type is seen in the *Chondrostei*, where the vertebræ never ossify. In *Lepidosteus* and *Amia*, they ossify in this stage.

I further specify the characters of the orders of *Physostomi* and the families they contain.

Ginglymodi.

Parietals in contact; pterotic and opisthotic absent; symplectic present. Mandible with coronoid, opercular, angular articular, and dentary bones. Basis cranii simple. Third superior pharyngeal bone small, lying on fourth; upper basihyal wanting. Maxillary subdivided. A præcoracoid arch. Vertebræ opisthocœlian. Pectoral fins with mesopterygium and five other basal elements.

One family, the *Lepidosteidæ*, with heterocercal tail, cartilaginous præcoracoid, one axial hyoid, and three basal branchihyals.

Halecomorphi.

Parietals in contact; pterotic and opisthotic present, and with basis cranii, and anterior vertebræ, simple. Mandible with opercular and coronoid; maxillary not segmented, bordering the mouth. Third superior pharyngeal lying on enlarged fourth; upper basihyal wanting. Vertebræ amphicœlian. Pectoral fins with mesopterygium and eight other elements.

One family, the *Amiidae* with heterocercal tail, cartilaginous præcoracoid, one axial and four basal branchihyals.

Nematognathi.

Parietals and supraoccipital confluent. Four anterior vertebræ co-ossified, and with ossicula auditus. No mesopterygium. Basis cranii and pterotic bone, simple; no coronoid bone. Third supe-

rior pharyngeal bone wanting or small, and resting on the fourth; second directed backwards. One or two pairs basal branchihyals; two pairs branchihyals. Suboperculum wanting, premaxillary forming mouth-border above. Interclavicles present.

This division is the nearest ally of the sturgeons (*Chondrostei*) among Physostomous fishes, and I imagine that future discoveries will prove that it has been derived from that division by descent. In the same way the Isospondylous fishes are nearest to the *Halecomorphi*, and have probably descended from some *Crossopterygian* near the *Haplistia*, through that order. There are great varieties of type in subordinate features, to be found in the *Nematognathi*. The affinity of the catfishes to the sturgeons is seen in the absence of symplectic, the rudimental maxillary bone, and, as observed by Parker, in the interclavicles. There is a superficial resemblance in the dermal bones. The rudimental mesopterygium shown by Gegenbauer to exist in the young *Siluridae*, the præcoracoid arch and the ventral fins, are shared with the sturgeons and other divisions.

There are considerable varieties of type in subordinate features to be observed in the Nematognathi. The *Hypophthalmidae* are indeed scarcely to be referred to this order.

1. Anterior vertebræ modified; inferior pharyngeal bones distinct; fewer branchiostegal radii.

Operculum present	*Siluridae.*
Operculum wanting	*Aspredinidae.*

2. Vertebræ unmodified; inferior pharyngeal bones united their whole length; many branchiostegal rays.

Operculum present	*Hypophthalmidae.*

In the *Siluridae* we have other modifications of importance. Thus in *Plotosus* the second superior pharyngeal is wanting. In *Loricaria* and its allies, the pterotic is greatly expanded, so as to unite with the hyomandibular and opercular bones.

Scyphophori.

Parietals narrow, distinct from each other and the supraoccipital. Pterotic large, funnel-shaped, enclosing a chamber which expands externally, and is covered by a lid-like bone. No symplectic. Opercular bones present. Anterior vertebræ unaltered. No mesopterygium. Basis cranii simple. No interclavicles.

This very distinct group is about equally allied to the preceding and the following. The arrangement of the parietal bones appears to explain that of the *Siluroids*, about which there is some difference of opinion among naturalists. Thus Huxley, in his memoir on the Ganoids, in his figure of *Clarias*, labels these confluent elements (as I suppose them to be at present) supraoccipitals. Parker (Shouldergirdle) calls them parietals. The families of this order are two, viz.: —

Tail isocercal	*Gymnarchidae.*
Tail diphycercal	*Mormyridae.*

In *Mormyons* there is one vertebra of the original series left in the tail.

Plectospondyli.

Parietals broad, distinct; pterotic normal; symplectic present. Opercular bones all present; no interclavicles. Anterior four vertebræ much modified, and with ossicula auditus.

1. Brain case produced between orbits; only two superior pharyngeal bones; basis cranii simple.

a. Only two basal branchihyals.

Tail diphycercal	*Catostomidae.*

aa. Three basal branchihyals.

Tail diphycercal	*Cyprinidae.* / *Cobitidae.*
Tail isocercal	*Sternopygidae.*

2. Brain case not produced between orbits, basis cranii double with muscular canal in many; four to one superior pharyngeal bones.

Three basal branchihyals	*Characinidae.* / *Erythrinidae.*

Isospondyli.

Parietals separate; symplectic present; no interclavicles. Anterior vertebræ simple, unmodified. Pharyngeal bones separate, above and below.

An extensive group, presenting many subordinate modifications.

1. Tail subisocercal; pterotic externally annular, enclosing a large cavity; basis cranii double. *Notopteridae.*

2. Tail diphycercal; pterotic normal; basis cranii double: supe-

rior pharyngeals four, distinct; third largest directed forwards; basal branchihyals three: (typical).

a. Parietals united.

Two tail vertebræ	*Hyodontidae.* *Albulidae.* *Elopidae.*
One tail vertebra	*Aulopidae.* *Coregonidae.* *Lutodiridae.*
No tail vertebræ	*Sauridae.* *Gonorhynchidae.*

aa. Parietals separated by supraoccipital.

Two tail vertebræ	*Alepocephalidae.* *Salmonidae.*
One tail vertebra	*Chirocentridae.* *Clupeidae.*

3. Tail diphycercal; pterotic normal; basis cranii simple. Basal branchihyals and superior pharyngeals, each three: *Osteoglossidae.*

The same bones each two. *Galaxiidae.* *Heterotidae.*

Haplomi.

No præcoracoid arch. Parietal bones separated by the supraoccipital. A symplectic; opercular bones present; anterior vertebræ unaltered. Pharyngeal bones distinct; the superior directed forwards, three or four in number. No interclavicles.

1. Basis cranii double; maxillary entering mouth border. *Esocidae.*

2. Basis cranii simple; maxillary bounding mouth. *Umbridae.*

3. Basis cranii simple; mouth bounded by premaxillary only; third upper pharyngeal enlarged. *Cyprinodontidae.* *Hypsaeidae.*

Glanencheli.

Parietal bones extensively in contact, distinct; pterotic normal; a symplectic. Opercular bones complete; mouth bounded by premaxillary chiefly; six or seven basilar pectoral rays. No præcoracoid or interclavicles. Anterior vertebræ united, modified, and with ossicula auditus. Superior pharyngeal bones subequal, continuous.

One family, the *Gymnotidae*, which approaches the eel-like *Siluridae*, the *Sternopygidae*, and the *Monopterus* of Java, so as to be in a measure intermediate between them. The characters are: no parietal fontanelle; four superior pharyngeals; three basal bran-

chihyals; brain prolonged between orbits. The structure of the fins, and the rudimental maxillary bones, distinguish this family from the *Sternopygidae*, with which they have been heretofore associated. In the first they are like the eels, in the latter the siluroids.

Ichthyocephali.

Epiclavicle suspended to posttemporal and to cranium; mouth bounded above by premaxillaries, which are in contact on the median line, and in contact with a distinct maxillary by the posterior margin; no interneural spines, pectoral fins, or symplectic bone; two basal branchihyal pairs. Vertebræ unaltered. Two pairs basihyals.

One family, the *Monopteridae*. Two (third and fourth) superior pharyngeal bones on each side. The general form is eel-like.

Holostomi.

Epiclavicle suspended to fourth vertebra, posttemporal wanting. Parietals in contact. Mouth bounded by the premaxillaries, which are in contact medially and bounded behind by maxillary. Symplectic present; vertebræ unaltered; no pectoral fin. Third superior pharyngeal not smaller than fourth.

One family, the *Symbranchidae*, with the genera *Amphipnous* and *Symbranchus*.

Enchelycephali.

Parietals in contact; lower pair of basihyals wanting. Scapular arch suspended to an anterior vertebra; no posttemporal; no symplectic; maxillary bone absent or connate with premaxillary, which forms border of mouth. Premaxillaries separated on the median line by the ethmoid. Superior branchihyals and inferior and superior pharyngeals well developed; the latter of three bones. Of these the fourth is largest and supports the third, which with the second is directed forwards.

1. Palatopterygoid arch completed; pectoral fins. *Congridae.*

2. Pectoral fins; palatopterygoid arch represented by incomplete pterygoid; premaxillaries more widely separated. { *Anguillidae.* / *Muraenesocidae.*

Colocephali.

Parietals largely in contact; opercular bones rudimental; the preoperculum generally wanting. Pterygoids rudimental or wanting;

ethmoid very wide. Symplectic, maxillary, basal branchihyals, superior and inferior pharyngeal bones, all wanting, except the fourth superior pharyngeal. This is jaw-like, and supported by a strong superior branchihyal; other superior branchihyals wanting or cartilaginous.

A glossohyal and osseous lateral branchihyals; four opercular bones; a scapular arch. *Rataburidae.**

No glossohyal nor osseous lateral branchihyals; three or fewer opercular bones; no scapular arch. *Muraenidae.*

It is evident from the above, that the eel-like form common to the last five orders is not more important in a systematic sense, than the fish-like form, which is common to so many of the others.

Physoclysti.

The following is an analytic synopsis of the orders. They all have the parietals entirely separated by the supraoccipital and lack the præcoracoid; the symplectic is present, except in *Ostracium*, where it is not ossified.

a. Scapular arch not suspended from the cranium.

Superior branchihyals and pharyngeals developed; inferiors developed; maxillary distinct. 15. *Opisthomi.*

aa. Scapular arch suspended from the cranium.

I. Ventral Fins Abdominal.

Branchial arches well developed, the bones present, except fourth superior pharyngeal; third complex, much enlarged; inferior pharyngeals distinct. 16. *Percesoces.* Mullet, &c.

Third and fourth superior pharyngeals much enlarged, inferior pharyngeals co-ossified. 17. *Synentognathi.* Soft gar.

Superior branchials and pharyngeals reduced in number; inferiors separate; interclavicles present. 18. *Hemibranchi.* Pipefishes.

Superior branchihyals and pharyngeals, and basal branchihyals wanting, gills tufted. 19. *Lophobranchi* (sea-horse).

II. Ventral Fins Thoracic or Jugular.

First vertebra united to cranium by suture; epiotics united behind superoccipital; basal pectoral radial bones elongate. 20. *Pediculati* (goose fish, &c.)

* Includes probably *Sphagebranchus.*

Posterior cephalic region normal, anterior twisted so as to bring both orbits on one side; inferior pharyngeals distinct. 21. *Heterosmata* (flounders).

Cranium normal, the premaxillaries usually co-ossified with the maxillaries behind, and the dentary with the articular; pharyngeal bones distinct. 22. *Plectognathi*, file fishes.

Cranium normal; bones of the jaws distinct; inferior pharyngeal bones distinct. 23. *Percomorphi*, perch.

Cranium normal; bones of the jaws distinct; third superior pharyngeal much enlarged, articulating with cranium; inferior pharyngeals co-ossified. 24. *Pharyngognathi* — Burgall, parrot-fish.

These orders will be more fully defined, and the families which are referable to them pointed out.

General Observations.

In tracing the affinities of the *Physostomi*, I have pointed out the relation between the *Chondrostei* and the *Nematognathi*, and between the *Halecomorphi* and the *Isospondyli*. The series commenced with the catfishes may be continued into the *Mormyri*, and then to the families of the *Plectospondyli*, where the series with altered vertebræ and with ossicula auditus terminates. The *Characins* have, however, considerable affinity to the *Isospondyli*, especially in the type of their branchial bones. From the latter group we pass to the *Haplomi*, and thence to the *Physoclyst* groups. The eel-like groups form a special line. The *Glanencheli* have cranial characters of the groups with modified vertebræ, with fins of the more typical eels. The latter show a steady approach in some points to the conditions characterizing the *Chondrostei*. The loss of the maxillary, of opercular bones, and of pharyngeal elements, reminds one of these, but in the loss of the premaxillary, and great development of the ethmoid, in the *Colocephali*, we have features quite unique. The vertebral position of the scapular arch is the only shark character they possess; while on the other hand, the *Holostomi* are undoubtedly related to the *Mastacembelus*, a real *Physoclyst* with spinous dorsal fin. These relations are as yet entirely inexplicable.

The affinities among the *Physoclysti* are more clear. Omitting the genus above mentioned, we find the four orders with ventral fins to form a true series, with a *Synentognath* variation, terminating in the greatly degraded order of *Lophobranchii*. The *Perceso-*

ces give us our nearest connection with the groups with abdominal ventral fins, and lead at once to the *Percomorphi*. From this centre radiate many lines of affinity. One leads from the *Chaetodontidae*, through the *Acronuridae* and to the *Plectognathi*, by the similarity in the arrangement of the posttemporal and forms of the pharyngeal apparatus. An important division of the *Percomorphi* has the basis cranii simple and the branchials reduced above; viz., the *Scyphobranchi*. The *Cottidae* are the most generalized family of this group, and lead on the one hand to the *Triglidae* of the *Distegi*, with which they are generally arranged, and, on the other, the *Blenniidae*. Some of the latter elongate the basal pectoral bones considerably, and lead to the *Batrachidae* on the one side, where the number of these bones is increased, and on the other to the *Pediculati*, where the number is diminished. To these groups the *Anacanthini* and *Heterosomata* are also allied.

The third upper pharyngeal bone has already presented an increase of mass and use in the first orders of *Physoclysti* with ventral fins. Among the *Percomorphi* the same increase makes its appearance by little beginnings in some *Sciaenidae*. It is quite noteworthy in most of the *Carangidae*, a group whose separation from the *Scombridae* by Günther is supported by this part of their organism. Through forms not now specified, approach to the *Pharyngognathi* is made. Here the pharyngeals are modified into a mill-like structure, which is least specialized in the *Embiotocidae*, and most so in the *Scaridae*.

These orders are more fully defined below, and the families which are referable to them pointed out.

Percesoces.

Ventrals anteriorly or posteriorly abdominal. Mouth formed by premaxillaries; posttemporal furcate, anteriorly, not suturally attached. Three basal branchihyals; all those of the superior series generally present. Superior pharyngeals with the third very largely developed, but not articulated to the cranium. Inferior pharyngeals distinct; basal pectoral rays four, short. Basis cranii without muscular tube, but with rudimental upper floor.

1. Dorsal fin of branched radii; no second floor of brain case; a transverse wing on inside of hyomandibular; second superior pharyngeal rod-like; first present, third simple. *Opheocephalidae.*

2. Dorsal fin of spinous and soft portion; no hyomandibular wing; second superior pharyngeal subconic, third very large, of two

horizontal laminæ, the superior supported by the inferior by a vertical rod. Superior branchihyals; second a triangular plate with superior exterior process; third and fourth triradial. *Mugilidae.*

3. Dorsal fin of spinous and soft portions, ventrals more abdominal; third superior pharyngeal long and wide, simple; second rod-like. Basis cranii with upper floor better developed. *Atherinidae.*

The family of *Cyprinodontidae* approaches the *Opheocephalidae* very closely, differing as to ordinal characters in the presence of the ductus pneumaticus. The form of the maxillary bone and anterior position of the ventral fins ally them to the *Mugilidae*, while the enlarged third superior pharyngeal even exceeds that of the *Atherinidae.* The physiognomy brings it into relation with this order.

Synentognathi.

Mouth bounded by the premaxillary only; parietal bone very much reduced; posttemporal slender, furcate; epiclavicle not distinct. Pectoral fin with elevated basis; no interclavicle. Superior pharyngeals: second and third large, oval, not articulated to cranium, sending processes forward; fourth wanting. Inferior pharyngeals co-ossified. Basis cranii double in front, but without muscular tube.

The only family of this order, the *Scombresocidae*, has a diphycercal tail and no spinous dorsal fin. In its rather weak superior branchihyals it shows resemblance to the next order.

Hemibranchii.

Mouth bounded above by premaxillary only; posttemporal not furcate. Pectoral fins elevated; interclavicles developed. Superior pharyngeals small, weak; second, third, and generally fourth present; branchihyals rudimental; the fourth, and sometimes others wanting. Inferior pharyngeals distinct. Branchial processes, narrow laminæ.

Basis cranii simple; no tube.

1. No first dorsal fin; dorsal vertebræ moderately elongate, united by suture; ? no suboperculum; second and third superior branchihyals, and third superior pharyngeal only present. *Pegasidae.*

2. Anterior vertebræ but little enlarged; dorsal spines strong; first, second, and third superior branchihyals, and second and third superior pharyngeals present. *Gasterosteidae.*

3. Four anterior dorsal vertebræ much elongate; (centrum and spine united by suture in Fistularia), dorsal spines very weak or none. *Fistulariidae.*

a. Superior branchihyals cartilage, three superior pharyngeals. *Aulostoma.*

b. Three anterior superior branchihyals osseous; three pharyngeals, directed forwards. *Fistularia.*

4. Four anterior vertebræ much elongate, with strong diapophyses, and normal articulations. Fourth superior branchihyal and first and fourth superior pharyngeal only wanting. *Centriscidae.*

5. Six anterior vertebræ extremely elongate, with normal articulations of centra. Fourth supra-branchihyal and all the superior pharyngeals wanting. *Amphisilidae.*

This very natural order connects the ordinary fishes immediately with the *Lophobranchii.*

The family *Gasterosteidae* is the least specialized of them, and presents some relationships to *Nematocentris* a genus of *Atherinidae* from Australia. The latter has flat, transverse, and serrate spinous rays to both dorsal fins, which both exhibit soft rays, as though in anticipation of their absence anteriorly in *Gasterosteus.* The relationships of this order to the *Lophobranchs* are numerous. They are, the weakening of the branchial apparatus, the presence of the interclavicles (which I find in all), the simplicity of the posttemporal bone and basis cranii; the shortness of the branchial processes: the prolongation of the muzzle and ganoid plates are characters of subordinate relationship. On the part of the *Lophobranchii* the *Solenostomidae* approach this order, but to which family I am not sure, probably to the *Fistulariidae.*

Lophobranchii.

Mouth bounded by the premaxillary above; posttemporal simple, co-ossified with the cranium. Basis cranii simple. Pectoral fins with elevated basis; well-developed interclavicles. Anterior vertebræ modified; the diapophyses much expanded. Inferior and superior branchihyals wanting or unossified. Branchial processes in tufts.

1. A weak spinous dorsal fin. *Solenostomidae.*

2. No spinous dorsal fin. { *Syngnathidae.* / *Hippocampidae.*

Pediculati.

Basal radii of pectoral fin elongate, reduced in number; no interclavicles. Epiotics united above behind supraoccipital, and the first vertebræ with the cranium by suture; posttemporal broad, flat, simple. Superior pharyngeals two similar, spatulate with anterior stem and transverse blade. Basis cranii simple.

Two families, the *Antennariidae* with three, the *Lophiidae* (*Lophius Halieutaea Malthe*) with two, basal pectoral radii. They connect with the *Percomorphi* by the *Blenniidae* and *Batrachidae.*

Heterosomata.

Cranium posteriorly normal; basis nearly simple; dorsal fin without spinous radii. Cranium anteriorly with twisted vertex, to allow of two orbits on one side, or one vertical and one lateral. Superior pharyngeals four, the third longest much extended forwards, inferiors separate.

Embraces the family of Pleuronectidae.

Plectognathi.

Cranium posteriorly normal, the posttemporal undivided co-ossified with the epiotic. The elements of the mandible, and usually the premaxillary and maxillary co-ossified. Interoperculum a slender rod. Superior pharyngeals laminar, usually vertical and transverse. A suboperculum.

1. Maxillary distinct; superior pharyngeals vertical, transverse, fourth present, minute. *Triacanthidae.*

2. Maxillary co-ossified; basis cranii double, with tube. Pharyngeals vertical, transverse; fourth wanting. *Balistidae.*

3. Maxillary co-ossified; a symplectic; basis cranii simple.

Pharyngeals transverse, vertical; fourth present. *Tetrodontidae.*

Same more longitudinal. *Diodontidae.*

Maxillary co-ossified; symplectic, not ossified; interclavicles present. Fourth superior pharyngeals wanting, second and third forming a vertical subcubic mass. *Ostraciidae.*

The contents of this order are heterogeneous, and it is questionable whether section fourth really belongs to it. The Plectognaths are associated with the true *perciform* fishes by *Triacanthus* on their part and the *Acronuridae* and *Chaetodontidae* on the other. Their affinities have never been in my estimation heretofore properly expressed in the systems, where they have always been

arranged at a distance from the higher *Physoclysti*. Yet the structure of the swim-bladder, skull, scapular arch, caudal vertebræ, pectoral fin, in fact every thing, combines to indicate their position to be here. The shortened jaws, especially the maxillary of *Acanthurus* remind one of *Triacanthus*, and its closely united, slender femora approach those of *Balistes*. The co-ossification of the simple posttemporal with the cranium confirms the affinity.

Percomorphi.

Bones of the mandible distinct; maxillary distinct. Cranium symmetrical; epiotics normal; no interclavicles; posttemporal not co-ossified with cranium. Basal pectoral radii not enlarged; humeri suspended (generally) from the scapular arch. Basibranchihyals three; inferior pharyngeals distinct; superior pharyngeals with the third generally largest. Sub and inter operculum present, plate-like.

This extensive order embraces a great variety of forms, some of which may yet be regarded as forming distinct orders. At present I am not sufficiently sure of their exact definition to admit them as such.

I. ANACANTHINI.

Basis cranii simple, no tube; posttemporal bifurcate; scapular foramen between scapula and coracoid. Superior pharyngeals three, horizontal, third little longer. Dorsal fin rays flexible jointed. Includes the families *Gadidae* and *Macruridae*, both with isocercal caudal vertebræ.

II. HAPLODOCI.

Basis cranii simple, flat; posttemporal simple, undivided. Scapular foramen in centre of scapula. Basal segments of pectoral fin five, elongate; superior pharyngeals contracted; first and fourth wanting; third basin-shaped with second adherent. Dorsal fin with some spinous rays.

One family the *Batrachidae*.

III. SCYPHOBRANCHII.

Basis cranii simple, no tube; posttemporal furcate; superior pharyngeals shortened; fourth and first generally wanting; third large, basin-shaped; second generally scale-like or co-ossified with third. Scapula with median foramen. Dorsal radii usually soft.

Families *Uranoscopidae*, *Gobiidae* (genera, *Gobius*, *Philypnus*, *Eleotris*, *Callionymus*, *Periophthalmus*, *Boleophthalmus*, *Amblyopus*, *Trypauchen*), *Blenniidae* (*Zoarces*, *Anarrhicas*, *Cryptacanthodes*, *Salarias*, *Centronotus*, *Cristiceps*), *Gobiesocidae* (*Gobiesox Sicyases*, *Lepadogaster*); *Cottidae* (*Uranidea*, *Cottus*, *Leptocottus*, *Hemitripterus*, *Scorpoennchthys*). *Aspidophoridae.*

IV. EPELASMIA.

Basis cranii double, with basal muscular tube; posttemporal undivided. Second, third, and fourth superior pharyngeals transverse vertical laminæ. Scapula with median foramen; basal pectoral bones four, short. Dorsal spines strong. Families *Acronuridae* (with *Amphacanthus*, *Acanthurus*, &c.,) and *Chaetodontidae* (with *Chætodon*, *Chelmo*, *Zanclus*, *Platax*, *Heniochus*, *Taurichthys*, *Epihippus*, and *Toxotes*.)

V. RHEGNOPTERI.

Basis cranii double with tube; posttemporal bifurcate; scapula with median foramen; superior pharyngeal bones four; third largest, narrow, directed forwards. Basal pectoral bones divided; two normal, supporting fin; one longitudinal without rays, and one a plate on coracoid, supporting elongate rays. Dorsal spines.

One family, the *Trichidiontidae.*

VI. DISTEGI.

Basis cranii double, with muscular tube. Posttemporal bifurcate; scapula with median foramen; basal pectorals three or four short, quadrate. Superior pharyngeals bones form; third always the largest; longitudinal, more or less elongate, not articulated to the cranium. Inferior pharyngeals separated. Dorsal fin with strong spines.

α. Third externally elongate, narrowed forwards; *Scombridae*, *Xiphiadidae*, *Trichiuridae.*

β. Third shorter, but narrowed; *Berycidae*, *Percidae* in part.

γ. Third nearly wide as long; *Percidae* pt. *Sparidae*, *Sciaenidae*, *Pristipomatidae*, *Triglidae* pt.

δ. Third much elongated into a grinder. *Sillaginidae*, *Carangidae* (Scyris, Blepharis, Lactarius, Drepane Equula, Trachynotus); *Echeneidae*, *Gerreidae*, *Heterognathidae*, *Amblodon* (fourth wanting).

δ. Third more or less basin-shaped; *Pterois*, *Synanceia*, *Scorpaena*, *Pelor* (tube rudimental,) *Peristedion*, (Triglapot).

VII. LABRYRINTHICI.

Basis cranii double, with muscular tube. Superior pharyngeals without the fourth; third massive articulated to cranium; one or other of the superior branchihyals developed into vertical laminæ, often involuted. Inferior pharyngeals distinct. Dorsal fin spinous.

I. Second superior pharyngeal present, superior branchihyals present, fourth greatly laminated. *Osphromenidae.*

II. Second superior pharyngeal wanting; first superior branchihyal with three laminæ.

α. Second and third superior branchihyals present. *Anabantidae* (Polyacanthus Anabas).

α α. Second (and third?) superior branchihyals wanting. *Helostoma.*

Pharyngognathi.

Basis cranii double with tube; basilar bones of pectoral four, short; scapula with median foramen. Cranium normal posteriorly; posttemporal bifurcate. Superior branchihyals not complicated; superior pharyngeals with the third greatly developed and attached by movable articulation to cranium, the others wanting or rudimental. Inferior pharyngeals solidly co-ossified.

1. Second and fourth superior pharyngeals present; second rod-like; fourth rudimental. *Embiotocidae.*

2. Fourth wanting; second flat, connate, dentate. *Chromididae.*

3. „ „ second rod-like, rudimental. *Labridae.*

4. „ „ second wanting; third articulated immovably to the fourth superior branchihyal. *Odax Gomphosus.*

5. Fourth wanting; second wanting; third articulated to fourth superior branchihyal by a sliding joint. *Scaridae.*

5. On the Extinct Tortoises of the Cretaceous of New Jersey. By Professor E. D. Cope, of Philadelphia, Pennsylvania.

(Abstract.)

His object was to explain two cases of "generalized groups," such as are not common, comparatively speaking, and are of much importance in the history of life. Generalized or synthetic groups of naturalists were explained to be those which combined the characters of others. They were generally found in earlier geologic time, while the more widely differing groups occurred later in time. The cases were as follows. It was explained that the existing division of the marine turtles (*Cheloniidæ*) possess sternal bones united by but few sutures, or with wide intervals; straight humerus and femur, and flat limbs, with truncate finger-bones incapable of flexion. It was shown that the existing snapping tortoises possess a narrow cross-shaped sternum with the bones everywhere united to each other, the femur and humerus curved, and the toes with hinge-jointed phalanges capable of much flexion. It was then pointed out that in the New Jersey Green sand a type of turtles is found, embracing several genera and species, in which the sternum has the elements generally united by sutures, except two central fontanelles, being thus intermediate between that of the *Cheloniidæ* and that of the Chelydras (snappers); that the femur and humerus are curved, as in the snappers, but the limbs are oar-like bodies with truncate phalanges, as in the sea-turtles. This family he called the *Propleuridæ*.

The second case was presented by tortoises of a character like those now inhabiting fresh waters. The *Emydidæ*, or common river tortoises of the northern hemisphere, were shown to possess ten horny shields on the plastron (or lower shell), to have a pelvis freely suspended from the carapace (upper shell), and a series of cervical vertebræ which can be curved in an S, and the head thereby drawn into the shell in a vertical plane. The southern hemisphere division of the *Pleurodira*, possesses eleven scuta of the plastron, a pelvis, of which the pubis and ischium unite by sutures with two corresponding elevations of the plastron, and a neck which cannot be sigmoidally flexed, but is thrown round to one side, like that of a bird, when it is necessary to conceal the head.

It was shown that in the Cretaceous of New Jersey there exists a family (the *Adocidæ*) which combines the features of these groups. It has eleven scuta of the plastron (the extra one being large and anterior), but the lower bones of the pelvis are not co-ossified with the plastron, though the latter rise in two corresponding elevations. The latter are evidently rudiments of the articulating knobs of the *Pleurodira*.

Professor Cope stated, moreover, that the *Adocidæ* possess a row of scuta across "the bridge," within the marginal row, such as exists in modern times in the sea-turtle, and in the Mississippi snapper, thus adding very much to the generalized character of the *Adocidæ*.

Turning to the tortoises of the Eocene beds of Fort Bridger, Wyoming, he showed that these are true *Emydidæ*, but that many of them retain the inter-marginal series of scutes, above-mentioned (*Baptemys*, &c.), so far resembling the *Adocidæ*. Among existing typical *Emydidæ*, but one genus presents the character, viz., the *Dermatemys* of Mexico.

The value of these generalized groups was pointed out as consisting in their correction of our views derived from the great constancy of specific characters. These, he showed, remained unaltered throughout great extents of time and space, and various slight structural characters endured through many geologic ages. Hence the value of cases where the association of characters is evidently in a transitional condition.

III. BOTANY.

1. INEQUILATERAL LEAVES. By W. J. BEAL, of Chicago, Illinois.

THE leaves of most plants, such as those of the white oak, sugar-maple, and tulip-tree, are equilateral, *i.e.*, the right and left sides are of the same size and match each other, as the two sides of the nose and chin, or the right hand and foot match the left. Some simple leaves and many leaflets of compound leaves show a marked

want of symmetry in their lobes. The *Begonia* is often cited as an example. The hickory, bean, and poison-ivy, may illustrate the same thing in compound leaves. In Fig. 1, "The homologous parts a, b, c, d, while they are unlike one another, are, in their main proportions, severally like the parts with which they are paired. And here let us not overlook a characteristic which is less conspicuous, but not less significant. Each of the lateral wings has winglets that are larger on the one side than on the other; and in each case the two sides are dissimilarly conditioned. Even in the several components of each wing may be traced a like divergence

Fig. 1. Compound Leaf. After Spencer.

from symmetry, along with a like inequality in the relations to the rest; the proximal half of each leaflet is habitually larger than the distal half." (Herbert Spencer, "Principles of Biology," Fig. 65, p. 31.)

A. P. De Candolle says, "This inequality generally exists only in alternate leaves, and I cannot find in my memoranda any example of an inequilateral opposite leaf. This fact tends to prove, that this inequality ought to be referred to the position of the leaf upon the plant favoring the development of one of its sides more than the other; and in this case, it is always the lower one which

is developed most. This law is still more evident in the leaflets of pinnate leaves: . . . the side most developed is always the lower, the upper being narrower and less prolonged. The same observation may be made upon the stipules, which are very frequently irregular. In opposite leaves, there has been presented a curious example of inequality in *Ruellia anisophylla;* — one of two opposite leaves is very small and narrow, and, as it were, abortive in comparison with the other; but symmetry is also met with in this irregularity, for, on comparing the successive pairs, the small leaf is found alternately on both sides. Stipules [sometimes] present analogous phenomena."

Dr. Wilder has shown that "Elm leaves have the *inner* or *upper* side much larger," thus upsetting De Candolle's theory that the inequality is due to the position of the leaf upon the stem. Various other reasons have been assigned for this inequality, all of which seem to fail when applied to numerous examples in their various stages of development.

Schleiden believes that this want of symmetry is due to unequal pressure in the bud. Spencer seems in doubt about the true cause, for he says, "How far such differences are due to the positions of the parts in the bud; how far the respective spaces available for the parts when unfolded affect them; and how far the parts are rendered unlike by unlikenesses in their relations to light, it is difficult to say. Probably, these several factors operate in all varieties of proportion." He attributes the want of symmetry in the leaves of the lime-tree or basswood to the shading of the smallest lobes. That this cannot be the case is proven by an examination of the conduplicate leaves of the basswood and elm while in the bud. When less than half an inch in length, the lobes are plainly unequal. When much less than a fourth of an inch long they are nearly or quite equal lobed. Since noticing these facts, the writer was pleased to find the same views recorded by Dr. Wilder.

On the basswood, the leaves are alternate and two ranked, having the upper lobe fullest. This is the case even where the full lobe is shaded or where the whole leaf is well exposed to the light. Spencer gives an illustration showing the arrangement of basswood leaves, exposing nearly all their upper surface to the light. If he should turn a young branch over, of this or almost any other plant, he might be surprised to see how soon the leaves would turn back again, and how nicely they would adapt themselves to each other, economizing all the available space. The leaves of red elm

and the American elm are sessile, broad at the base, two ranked with the upper lobe fullest. The same is true of the blue-beech, *Carpinus Americana*, though the lobes are often equilateral. *Celtis occidentalis* has two-ranked leaves with petioles half an inch

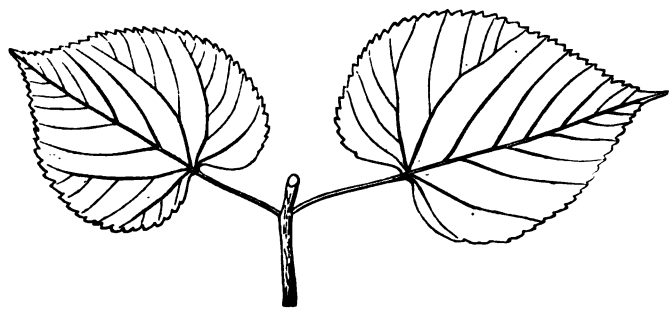

Fig. 2. Alternate two-ranked leaves of *Tilia Americana*, Basswood, fullest at the base on the inner side.

long. The upper lobes of the leaves are very full when compared with those of the elm. Begonia leaves are two-ranked with the upper lobe fullest, no matter whether they are nearly sessile or on petioles a foot in length.

The witch-hazel has two-ranked leaves with a broad base on short petioles and the lower lobe much the fuller. The common

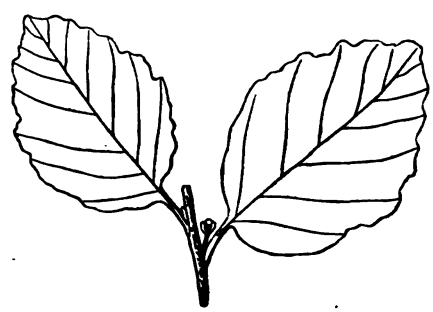

Fig. 3. Alternate two-ranked leaves of *Hamamelis Virginica*, Witch-Hazel, fullest at the base on the lower side.

beech, hazel, mulberry, and grape, have two-ranked, equal-lobed leaves.

It is a very common thing to see a want of symmetry in the lobes of leaflets of compound leaves. The reader will remember

that De Candolle says, "The upper edge of such is always smallest."

Of this character we find the black ash, the hop-tree (*Ptelea*), bean, hickory, elder, bladder-nut (*Staphylea*), strawberry, poison-ivy, fragrant sumach, and Jack-in-the-pulpit (*Arisæma*). The ultimate divisions of the decompound leaves of Hercules club are fullest on the lower side, while the leaves of the Kentucky coffee-

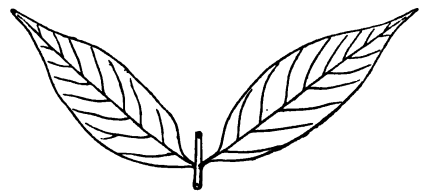

Fig. 4. Two leaflets of *Fraxinus sambucifolia*, Black Ash, fullest on the outer lobes.

tree reverse the above example. The leaflets of Ailanthus are broad at the base, and raised on very short pedicels. The upper edge of their leaflets is much the fuller. Leaflets of the Southern prickly ash are fuller on the upper side, while those of the Northern prickly ash, of the same genus, are usually fuller on the lower side. *Rhus toxicodendron* has the lower edge of the side leaflets fuller; *Rhus copalina* has the upper edge fuller. For some time,

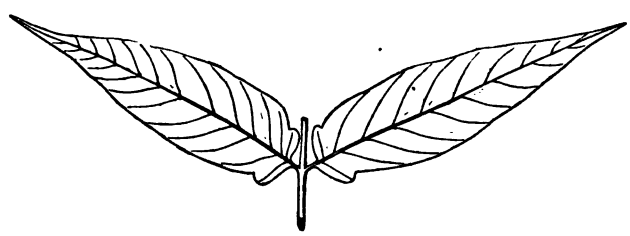

Fig. 5. Two leaflets of *Ailanthus glandulosus*, fullest on the inner side.

I thought as De Candolle wrote (though I had not then read his book on the subject) that the unequal-lobed leaves were all alternate; and, further, I thought they were all two ranked along the stem, and thus set off against each other, as leaflets in a compound leaf. I was not much surprised, however, though much interested, to find that the opposite leaves of *Cornus Florida* were fuller on the lower edge, as they were all turned horizontally

on the side branches. On the 4th of July, the two terminal leaves were about half grown and generally equal lobed at the base, though not always so. I find the opposite leaves of several of our Euphorbias, as noticed in Gray's manual, are fuller at the lower edge as they are turned down horizontally. In a somewhat similar manner are the two parts of the involucre of *Carpinus Americana*. These stand with the fuller edge away from the axis. The two edges of each are unequally serrate, more serrate on one edge than on the other; so the involucral leaves match as well as the corresponding fingers on our two hands. In the greenhouse of the Michigan State Agricultural College, is a plant unknown to me, presented by Dr. Gray. The leaves are on petioles three-fourths of an inch in length; they are probably three ranked (certainly not two ranked). As the leaves droop, the upper lobe is much fullest, and the midrib considerably curved, as in *Begonia*.

Fig. 6. Two opposite leaves of *Euphorbia maculata*, fullest on the lower side.

Fig. 7. Involucre of *Carpinus Americana*, Blue Beech, the upper or inner lobe narrower which grew next the axis.

So we have unequal lobed leaves on stems where they are two, three, or four ranked. The common sheep sorrel often has one lobe longer and larger at the base, but I am unable to find any rule with regard to this fact.

The four o'clock of our gardens, *Mirabilis*, has opposite leaves, and, when of proper size, terminates each axis with a flower. The axillary bud on each side develops into a branch terminating in the same manner by a flower. Thus we have four leaves in two pairs closely sitting about a flower. As thus arranged spreading each way they are all fuller at the base on the side next the flower, where there is least light and least room. This is contrary to what we should expect according to De Candolle and Spencer. An examination of the plant for a moment will make it clear.

Every botanist is familiar with the unsymmetrical petals on the sides of the pea flower, violet, lobes of mint blossom, and those of other plants.

The strangest thing under *want of symmetry* that I have seen in plants is found in the cotyledons of our cultivated buckwheat. While in the seed, they are pressed together and rolled up from one edge. When the cotyledons have acquired their full growth they have petioles about half an inch long; *each* cotyledon is fullest on its *left* side, so they would not match each other without turning one of them over. Perhaps this is a puzzle analogous to homologizing the hand and foot on the same side of the body. All our theories so far, read or imagined, such as influence of heat, light, gravitation, number of ranks on the stem, length of petiole, pressure, natural selection, do not satisfactorily explain all these peculiarities.

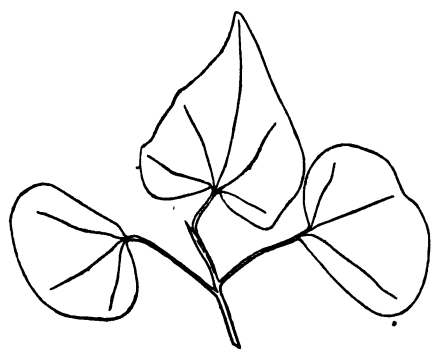

Fig. 8. Cotyledons of *Fagopyrum esculentum*, Buckwheat, each fullest on right lobe.

So far we agree with Dr. Wilder, "That such peculiarities are true and original characteristics of the plants, and that they are produced by the so-called vital force acting in a definite way."

2. The Fresh-Water Algæ as the Spawns of Mosses. By Theodore C. Hilgard, of St. Louis, Missouri.

Chlorospermeæ.

About fifteen years ago, Professor W. H. Harvey, Author of "The Nereïs Boreali-Americana" (Smith. Contr. Knowl., vol. x., p. 3), discoursed in the following manner on the contemporaneous state of our knowledge, of the then perplexed question of the nature of Chlorospermeæ, or so-called Fresh-Water Algæ:—

"Much still remains to be done in tracing the development of these Algæ, more especially in studying the transformations which many of them undergo. Very many have two or three different modes of reproducing the species, as by self-division, by zoöspores, or gemmæ, and by properly fertilized spores; and the individuals resulting from these various modes of growth are not always similar. Thus there is in many an 'alternation of generations,' to be studied, such as has been noticed among lower animals; and, probably, when the subject has been properly worked out, a large number, not only of species, but of genera, especially among the fresh-water kinds, must be erased from our lists. It now appears probable to Pringsheim that many of the minute unicellular Algæ of Braun are the male organs or *androspores* of other Algæ. I think it can hardly be questioned that multitudes of the Palmelloid forms are either spores or imperfectly developed fronds; and the same is probable of many Confervoids. As yet the subject, except in a few able hands, has been confused rather than rendered more clear by the labor bestowed by authors upon it. There has been too great an anxiety to establish new genera and species, without due regard being had to circumstances of growth and development; and the unfortunate student who now attempts to study the fresh-water Algæ is oppressed by an accumulating mass of bad species and genera, which all have to be in some degree mastered before he can make *clean work*. Add to this, that in the present state of our knowledge it is absolutely necessary, in most instances, to have the living plant at hand, and it will be understood what a difficult task it must be to give a good account of the Chlorospermatous series of the Algæ."

Thus far Professor Harvey.

About fifteen years ago, I accidentally turned my attention to some protococcoid vegetations before then unknown to me; the continued developmental observation of which, however, insensibly and unexpectedly led me into the discovery of the great circuit of generations of all the tribes, and most of the component (*titular*)

genera of so-called "fresh-water algæ;" exclusive however, of Batrachospermeæ (the full development of which is not known to me), and of Characeæ, whose known germination and "disporous" organization have already secured them a partial acknowledgment as allies of the "disporous Ferns."

As for the Batrachospermeæ, they evidently closely connect with certain filiformly dissected "hepatic Mosses," such as, *e.g.*, Trichocolea (Jungermannia). They thus probably fill the position between these and such true Fucaceæ or genuine *algæ*, as, *e.g.*, Wrangelia (Harvey's Nereïs, tab. xxxiv. B.)

As early as July 1st, 1861, I communicated to the St. Louis Academy of Sciences the results of my investigations (not then published for want of funds for plates) in a detailed manner, the gist of which I expressed in the "minutes" as follows; viz., "that the observed forms of such *desultory brooding-phases* (*leprous*, *oscillarious*, *desmidiaceo-confervaceous*, *nostochine*, *protococcous*, *hydrodictyine*), all concur in forming one and the same circuit of generations of the thallus of BRYACEÆ,—mostly Bryum argenteum and Funaria hygrometrica, Syrrhopodon, Hypnum, &c.

"*Protophyta*" and "*Protozoa*."

At a previous meeting of this Association, at Chicago, August, 1868, I have exhibited the same canvas drawings which you now see in our Microscopist's section. They show in detail the *actual and connected conditional modes of development of all the types of so-called "protophyta," "protozoa," "infusoria," "ferments," and "fresh-water algæ,"*—such as directly ascertained by myself, by experimental microscopic investigation during the last fifteen years.

The phases and processes of growth of the true "*yeast*," *and cadaverous corruptive* proper, I have described and figured in our last year's "Proceedings." The parts played by the bryaceous broods, as the sixty-four *titular* "genera" of "Fresh-Water Algæ," form the subject of the present paper. As for the truly *animal* forms here implicated, they *all* belong to types so "highly organized" in their adult condition, that any doubt as to their nature or affinity is absolutely out of question. Besides such minute scutellate or "crustacean" forms, as, *e.g.*, Cyclops, Monoculus, Noteus, Trichoda, &c. (leaving aside the polypous Hydra and its yet-to-be-explored hibernation, &c.*) the (*terebelloid*) well-known Rotifer, as

* I find it necessary to emphasize this with particular reference to such unexplored forms as the ("profound") *Bathybius*, "*Pelobius*," &c.

well as Brachionus, are all provided with a complete set of animal *viscera*, which it is impossible to confound with any vegetable formation, at least of cryptogamous plants. The great (and hitherto unexplored) bulk of so-called Infusoria — exclusive of the so-called "flagellate Infusoria" or fresh-water *moss-spawns* — are all subsumed in the enormously diversified *germinal cell-multiplications* — or so-called circuit of generations — of the "Vorticello-Planarian" tribe of microscopic *fluke-worms*. As such they likewise partake of the typically *radiate-stratified* visceral organization of all animals, no less than of the entire Flowering Kingdom! It is only in a late embryonic stage, that these radiately disposed viscera become enfolded within the (*pod*-like) longitudinal furrows of the overlapping "animal leaves" of embryology; viz., the "hemal" and "neural" visceral cavities respectively.

The Planarian Germs.

The "vorticello-planarian" circuit of generations (as first verbally communicated by me to the Chicago Meeting, and subsequently published in the August Nos., 7 and 8, 1871, of the American Journal of Arts and Sciences) chiefly comprises these leading forms of germinal, molecular, or vitelline life-phases; viz., the "germinal clouds" of fertile (vorticellan, paramecian, &c.) self-dissolution; the so-called "amœba" or pseudopodial tumbling-sacs; the "vibrio termo" or seminal cartridges; the "vorticellæ," their buds and pellets, their "oxytricha" development; the oxytricha pellets or "zoöglœa" (Cohn; *nec* Klob); the §-shaped individual molecules — the future "colpoda"-grubs — thence escaping; the accompanying currant-shaped vesicles developing into the "scabbarded" oxytricha-young, afterwards moulted as "oxytricha" proper; the oyster-shaped or book-like "porte-monnaie" grub; its encystment into a "gregarina"-couple of young "paramecium;" and the adult form of the latter, properly classed as a fresh-water *Planaria*. The visceral (or assimilative and secretive) organization of the latter can nowise be misconstrued into the well-known adult forms of either the yeast (or *common mould*); or any other adult *plant* or "fungus" whatsoever!

After the contradistinctive exclusion of these animal Planarian germs on the one hand, and the fermentic developments on the other, I can now proceed to give a short written synopsis of the remainder — viz., the various *pseudo*-genera of fresh-water algæ —

likewise; thus exhausting the entire domain of "questionable" fresh-water germ-life.

The "Clay-Bloom."

A name is still wanting for the first appearance of these "chlorospermous" moss-spawns, in the shape of a *chalk-white fovilla*, or snowy-looking "powdering," efflorescent from all clayey and fertile soils, after the first frosts and thaws in winter; but most luxuriant in early spring, and otherwise appearing throughout the year.

In former treatises and communications, I have called it "clay-bloom." The same, as heretofore indicated in various printed communications on this subject,* is also formed on any parcel of soil protected from abrasion, and in a tolerably damp atmosphere; as on all crumbs of flower-pots, when moistened only from underneath; blooming forth (as the forerunner of all the "chlorospermous" and *bryoid* subsequent developments, *in loco*) on the outside of the flower-pot itself, from the moisture which percolates through the crockery, in very white, cloud-like, mealy efflorescences as of a gum, or of grape-sugar.†

The spot now begins, from underneath upward, to breed into a more luxuriant, thickening "chalky" or "sugared" surface coating, and downward into a homogeneous, glass-green, coherent gelatinous cuticle of uniform cells, and now might be classed — as the fashion is — as some "*ulva*."

When wetted, under the microscope, this very subtle, white substance, of particles about $\frac{1}{3000}$ of a line in bulk, begins to absorb moisture. The now quite colorless particles very rapidly assume the well-known "saltatory" or *vibratile* motion as seen in all germinal matter (variously called monads, zoöspores, &c.), being much like what I have proposed to call *vibrios* (as a technical *genus grammaticum*, only) in last year's communication on the fermentive agent. In this case they are frequently rather larger than the average size, *e.g.*, of the intracellular, "rotating protoplasm" vibrios which are seen travelling along, inside of large fungous fibres; or that compose the travelling (red-tailed?) nucleolar molecules of "Closterium," so-called.

* Amer. Journ. Sci., No. 7, July, 1871, p. 22, foot-note.

† Associated as this first germinal, bryaceous *gum of the soil* is, with its amorphous (partly "Navicula"-shaped) silica-educts and assimilated silica proper, it might perhaps deserve a due consideration as the βδέλλιον — "found in this (our) soil" — associated with the "ὄνυξ" in the Noachite genesis likewise.

The Chlamydococcus.

When washed into gutters, pools, &c., they rapidly enlarge and mostly assume the form of "chlamydococcus," — a green oval-coated cell from $\frac{1}{2000}$th to $\frac{1}{100}$th line in bulk, tending or roving spontaneously toward the light by a single apical *flagellum* or vibratile lash, arising from a clear point of substance. This belongs to the common *silver-moss* — *Bryum argenteum* — in most cases of clayey pools; whereas in manured or ashy ones the "protococcus" of another frequent form, that of *Funaria hygrometrica*, prevails. It is here evident that the fittest wins the day over the less competent species. The first coatless cell-bodies of the latter moss (which also produces the so-called "hæmatococcus," or "blood alga" on slippery, manured spots) are rather smaller, naked, very globular, with a delicately aciculated surface. They are most probably covered with the minute *flagelli* of their own constituent particles of naked endochrome, and therefore revolve in every sense equally. At first, they closely resemble the macerated blood (or pus) corpuscles, or the "colostrum bodies." They never attain the size of the (coated) "chlamydococcus;" their subsequent "eu glena" (or peristaltic-sarcode form) has a more pointed rear end, is apt to contract its middle into a wheel-and-axle shape, becomes "still" (or "encysted") *without* a membrane, and on dissolution its constituent endochrome beadlets form a broader "oscillaria" than in the case of the silver-moss. In other cases, as, *e.g.*, in the bilge-water of wooden wharf-boats, the corresponding forms of a certain species of Hypnum take exclusive possession of the premises.

The sequel of this representation will be mostly confined to the developments of the common silver-moss, as the dominant and most massive form in all the clayey formations of the great Mississippi Valley.

Hæmatococcus.

When left undisturbed on land, the "clay-bloom" first turns up in granular lumps resembling half-toasted "*corn-meal*," but of a gummy or semi-gelatinous consistency. The next step of this terraqueous life-agent — of a bryaceous nature — is, to turn into an ulvaceous, uniform cell-layer, crested with the constantly increasing white *fovilla*, by the spontaneous maceration of its daughter-cells into colorless molecules.

In the form belonging to the silver-moss, this pale-green, scanty "ulva" does not now change color. In the case of Funaria hygrometrica (the sessile and star-like tufted, broad-leaved moss), the *ulva* is apt to become very luxuriant, and its daughter-cells suddenly turn of a deep crimson hue. It is now called a "hæmatococcus," as a special (*pseudo-*) genus. Its component secondary or daughter-cells resemble actual blood-corpuscles both as to size and color (apart from their globular shape), and their punctiform contents are apt to burst forth as fresh capping crests of clay-bloom; or, suddenly acquiring a very dark-green lustre, its augmented molecules, vibrating and jerking at the touch of rain or water, immediately lengthen out — *in even calibre* — into the straight, wiry fibrils (resembling so many microscopic knitting-needles) that compose the blackish lubricity on land and water known as the (*pseudo-*) "genus Oscillaria."

The same occurs with the "ulva" of all other mosses.

Oscillaria.

The wiry "oscillaria" fibril consists of a thickish cylindrical confine, inclosing nummiformly dissected contents. On land they lie immovable, and grow apace in snake-like, viscid fascicles (called "oscillaria chthonoblastes"); while each fibre, separating from the rest by contact with and in water, assumes a well-known longitudinal spontaneous locomotion. Under the microscope its fascicles, when wetted, are apt to spread apart as if electrified, curving round. Not unfrequently a single fibre makes a *shift* among its parallel companions, and then exhibits that *whirring* motion from which its name was derived. On land, it now covers the ulvaceous spot, which then has turned of a blackish, verdigris lustre. Under its protection the underlying ulva cells, largely increasing in size, acquire a very thick hyaline "albumen" zone, — like that of an egg, — and a thin membrane (*pseudo-* "genus Glœocapsa"); when the latter lengthens into long, band-like, *lumbricoid* sheaths, and its endochrome correspondingly lengthens out into "oscillaria" fibrils, it now "takes the name" — or assumes the characters of — (*pseudo-*) "genus Microcoleus."

Glœocapsa.

The centre of the *glœocapsa* cell turns of a very lively green, and otherwise now resembles a compact yolk; whence by segmentation

glairy-coated daughter-cells, about $\frac{1}{300}$th line in bulk, are then produced. The confining general membrane now casts a finely tapering, meandering, and ramified *root, all of one single piece*, with fibrils about $\frac{1}{1000}$th line in thickness; while the daughter-cells, by cross-septation now elongating upwards, rise as a *rooted tuft* or pencil of jointed hair, and are now "classed" as a *pseudo*-genus "Rhizoclonium." In these and all similar processes the jelly and confining membrane spontaneously dissolve into a solution of glutinous substance, which is perfectly transparent, and often in the clearest pond-water gives abundant occasion for the most pernicious, gangrenous putrefaction of such abodes. Under the influence of the common yeast or corruptive fungus (in its adult stage sufficiently identified as pseudo-genus "Mucor"), all shore-deposits of "confervaceæ," no less than all waters wherein confervaceous life undergoes a retrograde development, evolve a vast amount of putrid gases, which, however, in a dilute condition, become perceptible merely as "flattish air."

Rhizoclonium.

As these tuftlets of the jointed *rhizoclonium* first arise in the shape of a wart or "frambœsia," a molecular-dotted mass remains in the centre, which, as the fascicle arises, is upborne on a stouter central stalk. As in the parallel case of stored conferva-pellets, *this glutinous germinal speck directly organizes into a perfect moss-bud*, composed of bright-green conjugate ("cosmarioid") cells. As in other cases, the endochrome of these first cells is discharged into a reticular system of coherent cells, surrounding them, as at the base of other developing moss-leaves, and the same remains visible in the adult condition in the group of "peat-mosses," or Sphagnum.

The Moss-Buds.

The bryaceous bud or true (leaved) moss forms the last joint of the central file. Its base consists of a brown, rootless *internode* — not a true root, — which at the touch of water at once is *thrown off* by the elastic swelling of the underlying and all other cells; these, at that state of maturity readily seceding or crumbling apart from one another, at once start on an independent confervaceous or "prothalline" development, exactly in the well-known manner of both true "moss-*spores*," and all the well-known crumbling, "proliferous cells" of moss-leaves, buds, stems, and their radical and caudal hairs in general. Each desultory cell now of course con-

stitutes what was classed as a (*pseudo-*) genus "Protococcus," that is to say, "*any green brood-cell whatever*, capable of individual development"! It has been known, however, for several decennia, that both the chlorophyl stratum of lichens, and all chlorophylliferous organs of mosses, are apt to multiply by such detached "brood-cells" of their own kind, developing into their own especial kindred.

The "*caudex*," corm, or internode of the moss-bud thus originated, now readily casts out its broad and blunt, pinkish and band-like, flattened roots (about $\frac{1}{200}$th line in diameter), *sidewise* into the surrounding ground; not as a "tap"-root, as the original *rhizoclonium* (or *glœocapsa*) mother-cell had it.

The further development of the last, adult, or bryoid development phase of mosses is sufficiently known as that of "Mosses."

It is here that a *radial organization first commences*. A definite axis and radiating organs are formed. A stem and leaf-bud are the results. A (so-called) "sexual" fructification here finally ensues. "Antheridia" are formed, which discharge a semen composed of spermoid-flagellate molecules (as in the entire Organic Kingdoms), which here alight upon a pervious stigmatic prolongation * of a follicle, just as in the "fructification" of flowering plants. This follicle is originally sessile; but by dint of the violent elongation of a stipe, resembling a seed-chord, the follicle is ruptured, and thus borne aloft it is called a "calyptra."

The pyriform or cylindric *theca* which terminates the stipe has a lid, or "opercle," in exact likeness of the lid upon the true seed of Gnetaceæ.† It otherwise consists of a double coat (forming a double "peristome"), like all true seeds; but, instead of containing an embryo formed of connected cells, it is replete with *disconnected* cells, vastly resembling the pollen of higher plants.

The Moss-Spore.

This apparent pollen, or so-called "true" moss-spores, as is now well known, when alighting on a suitable soil, directly lengthen out into terraneous "confervaceous" prothallia, *by way of true*

* Such, it is well known, is likewise the case with the Lemnaceæ or duck-meats. A true pervious stigma — as I have specified in a separate paper — also obtains in all the Gnetaceæ, Cycads, and Coniferæ.

† See figures of Hooker's Welwitschia, &c., and "The Organic Identity of the Albumen and Endopleura of Seeds," in this volume.

germination. This terraneous "Conferva," "Vaucheria," &c. *Auct.* consists either of apparently unseptated, ramified, and gibbose tubuli (resembling blown glass), which are thus claimed as "Vaucheria;" or their tumid-jointed, thick-coated, and septated, ramified fibres (classed as "Conferva," "Cladophora," &c., — and resembling the valvate-jointed texture of the lymph-vessels of animal fabrics) now form the first bulb-like or conical *leaf or "radial element,"* at the apex; by enlargement and increased septation of the terminal joint or cell of the fibre.

Professor W. P. Schimper's excellent "Recherches sur les Mousses" (Strasburg, 1848) contain a vast amount of direct experimental observations on this point, as likewise on the conditional aquatic or paludal developments of true moss-spores directly into the aquatic "Confervaceæ."

These observations of Professor W. P. Schimper (a brother of Carl Schimper, the first discoverer of the laws of *phyllotaxy*) were also repeated and amplified by my esteemed friend, Dr. Siegmund Reyssek, at Vienna, Austria. From him I learned (in 1851), that "according to his own experiments, the true moss-spores, when introduced into pond-water, directly and substantially elongating, produce interminable repetitions of pullulations in the shape of true 'Confervaceæ,' so-called."

The Water-Hemp Pellet.

Anterior to my communications to the St. Louis Acad. Sci., July 1, 1861, I had found occasion to *investigate* — and thus *establish* — the return of conferva, or the so-called common water-hemp (*pseudo*-genus "Cladophora") into its adult or bryaceous phases, in the following fashion. At certain seasons, in high summer, the water-hemp, while rearward dissolving, *ut fit*, and liberating countless infinitesimal endochrome-molecules, on its *progressive* embranchments produces, out of its own superficial and internal asperities, first a cluster of gelatinous pellets, borne on very minute, scraggy, and ramified hair, *directly protruded from within.* The minute pellets, gradually assuming a bright vermilion color as they increase in size, are now seen substantially coating say every fifth or sixth joint as with a scarlet raspberry, somewhat in the fashion of craw-fish roe. When the water-hemp is drifted upon the beach, by subsidence, &c., the vermilion pellets, now changing color and enlarging a good deal, swell into large cells with pallid verdigris contents.

The latter appear semi-gelatinous, and serially punctuated with molecules imbedded in an apparently amorphous slime; which would thus bring this phase under head of a "Nostoc globulare." *Auct.* As it amplifies, some of its seriated molecular strings, acquiring a cell-wall, are seen sprouting forth in the fashion of a *crimped* rhizoclonium or moss-velvet; as a convolute enveloping the gelatinous ball, or *yolk*, so to speak. The hair thus formed would claim the appellative of "Œdogonium" (as it subsequently takes its aquatic development); while on the mire it might serve as a "Rhizoclonium," but for being rootless. In the underlying masses, the enlarged yolks are protected from exsiccation by the darkly olivaceous, glutinous slime — or "Nostoc" — caused by the copious diffluence and rapid "nostochine" growth of *diffluent yolks* exposed to the air; while underneath, in a protected condition, *a circular area* (in exact likeness of the "germinal speck" of animal yolks) *is formed on the apex of each pellet*, and by self-segmentation *forms into the first leaf-cells of the true moss-bud* — much like the germ-cells of the animal embryo, and altogether in the manner of the *rhizoclonium*-pellets.

The Moss-Embryo.

At first the embryonic area divides by fission, by twos, fours, &c. The beads are coatless, — no cells; but protoplasm bodies. The cells are first *formed in a heap without a stalk or root*, and without a confining membrane. At this period — *e.g.*, of quaternary division — the slightest touch of water causes these copular bodies to separate in the form of a true (bicordate) *cosmarium* — to avail myself of the idiom of the system at present in use. At a later period, they no longer separate. As the interstitial retiform or secondary cells are formed, the first (bulb-like) leaf is built up. It is only afterwards, when several leaf-rudiments are preformed, that a stubble-shaped, basal internode — or corm — becomes manifest. The bud is completely organized, before the pinkish side-roots break forth from the turmaline-colored corm or podetium. The plant here formed is at first both stem- and root-less, and altogether in an embryonic condition. The more weakly stems or branches form (as usual with the dimorphous mosses, such as the common silver-moss) only the "cucullate" variety of leaves, while the stouter ones or central axes bear leaf-buds which are pointed like a hair-pencil. No doubt the aquatic development of the verdigris

or vermilion pellets is into the bicordate "Cosmarium" and its various progenies.

Land-Oscillaria.

When, on land, the dark-green *ulva* (or red *hæmato coccus*) is touched or battered by rain, the daughter-cells of the same can be seen jerking about (like so many microscopic fleas, trying to shift); and when finally settled, they at once start, *in loco*, on a quick development into bulky oscillaria ("Chthonoblastes") fibres; forming the well-known blackish-verdigris lubricity of such places.

The same is found floating on top of heated pools, or seen upheaved in sluggish streams and sewers, — floating an immense amount of putrescent material into the running watercourses.*

When settled or transplanted on open ground, or upon ground taken on a saucer and protected from exsiccation, under an inverted tumbler, and under a moderate influence of light, the aquatic "Oscillaria" follows exactly the same routine as that which spontaneously originated on the land, out of the omnipresent, wafted, atmospheric, no less than the soil-imbuing, vibrionic moss-spawns.

The Mud-Blister.

When such sluggish waters, &c., subside, leaving the wet mud densely covered with a thick oscillaria coat as a black slime, in a few hours the whole will be found sprouting with *large blisters, of pin-head size*, and closely set so as to touch mutually, and audibly decrepitating under the foot.

I have never yet been able to trace the immediate origin of these "mud-blisters," nor have others been more successful. In every respect they represent a huge *glœocapsa*-cell; being inflated with an aqueous humor, having a branched root (with blunt ends, however), and containing several large *yolk-like pellets with an albuminous zone.* As each single vesicle occupies the comparatively large space of about a millimeter diameter on the ground, the original cell-elements, which have thus developed, must necessarily form but a scanty percentage; although on the ground they stand often as closely packed as clustering grape-berries. No doubt the cell which gives them origin lies under the slimy coat, or lay buried in the *mire itself.* In a more recent condition the blister contains only molecular chlorophyl in an aqueous dilution, and then is called

* Proceedings A. A. A. S., 1871, p. 316.

(*pseudo*-gen.) "Hydrogastrum." In a few hours, large pellets or *vitelli*, so to speak, form in the interior, while the thickening skin is somewhat roughened and pruinose by cracked slime. It had been misconstrued, in this condition, into a Hepatic, and been elegantly figured, on false suppositions, by *Micheli*, who calls it "*Genus* Sphærocarpus," and represents its surface as composed of a network of cells, and its pellets as quadri-compound fern-spores. It is thus copied into "Bischoff's Botanik." Dr. Asa Gray figures it a good deal more according to nature, and justly disclaims the representation of Micheli. It has been described by Wallroth, Kuetzing, Alex. Braun of Berlin, &c., under the name of "Botrydium, *Wallroth*," and more recently been made famous on the other side of the sea as "the newly discovered American fever-plant, Protuberans, Agz." — as a "Palmellacea."* The true clew to its nature, however, is gained by the observation of its ulterior developments, as occurring in shaded positions.

Moss-Bud of Sphærocarpus.

The blister here mollifies, and is seen slowly collapsing into a flat gelatinous cake; neither drying up, as in sun-exposures, nor bursting, as when submerged. The enclosed *pellets are now observed segmenting, exactly in the manner of the rhizoclonium and conferval yolklets, forming the rootless moss-bud and corm*, as in the above cases. After casting the band-like roots sidewise, the several moss-buds now are seen rising and gradually piercing through the already

* With reference to the original article on this subject, in the Amer. Journ. Med. Sci., January, 1866, it may not be uninteresting to learn that on that occasion no less than half a hundred supposed "new species" and several "new genera" were launched upon the domain of "diagnostic" botany; all consisting of the very commonest and most ubiquitous of the known so-called Chlorospermeæ.

From Diodorus Siculus, Book i., chap. 7, it is probable that the "mud-blister," as an instance of uncommonly rapid development out of invisible germs, was not unknown to the Egyptian priests, in whose cosmogony it played a part: *nil novi sub sole*. The full baptismal credentials of this form alone will explain why further references are omitted: *ancient Ægyptian name* (unknown). *Sepedones*, Diod. Sic., about the Christian era. *Ulva granulata*, Linnæus (referred to 1633). *Sphærocarpus*, Micheli, 1729. *Ulva radicata*, Retzius, 1795, *Valoniæ spp.*; *Vaucheria radicata*, Agardh. *Botrydium granulatum*, Greville, 1821–36. *Rhizococcum crepitans*, Desmazières, 1831; *Botrydium argillaceum*, Wallroth, 1833. *Hydrogastrum*, Desv. *Protuberans*, Agassiz, 1866.

Quarante siècles vous contemplent! Of these moss-spawns about sixty titular genera are upheld to the present day, involving the labors of about fifty-seven authors on such subjects.

mollified membrane, and emerge, hung around with the adhering, darkly olivaceous, "nostochine" deliquescence of the surrounding balloon. As in all similar cases, the molecular substance assumes the form of serpentine bead-strings, like pater-nosters alternately relieved by a larger bead, at regular intervals, and imbedded in a copious "amorphous" gelatine.

The Nostoc.

The single beadlets of these pater-nosters (claimed as a peculiar *ps.* genus "Nostoc") very soon are seen partly to multiply, by cross-division; or immediately lengthening out — in equal calibre — into *oscillaria*-fibrils of corresponding diameter. The blackish-brown *nostoc* patches here turn of a bluish verdigris color, which characterizes their transition into oscillaria sprigs; a process requiring only a few days. This onward development is common to all *nostoc* derived from the actual deliquescence of confervaceous, &c., moss-spawns, as well as that generated by their "navicular," silica-coated cells increasing into "Nostoc" by cross-segmentation. A similar form, however, likewise called "Nostoc," occurs with the collematous Lichens (gen. Collema) although remarkable for its delicately *denticulate* self-division, &c. This refers particularly to *Collema humosum;* of which one (dusky) form bears so-called "spermogones" (resembling Sphæriæ), and detaches pellets of a vivid green nostoc, which, affixing itself into the soil, brings forth the "apothecium" or *asciferous* form of the plant. Of the famous "Nostoc rivulare" — resembling boiled tea-leaves and lying strewn about as a loose, bloated jelly on rich humid grounds—I have never yet succeeded in reproducing any thing but itself. It probably, however, belongs to the *collematous* nostocs of Lichens resting on the damp soil and along the cracks of stones in scanty rivulets. The fact is, that with a great many Lichens all endochrome is formed of "nostochine" bead-strings, — terminating the otherwise thin and fungoid tissue-fibres. (In some Lichens, however, it forms in nuggets or clusters by tessellar division.)

I have found all the varied forms of "confervaceous," "palmellaceous," &c., nostocs, of a springy glade, covered with bulrushes, *all combined into one compact ulvaceous tissue.* All went through their contingent nostochine diffluence, and under the then prevailing circumstances that *nostoc* did not develop its single granules into oscillaria fibres, but all and every nostoc in whatever mode produced, entered into the formation of a leathery, "*light-green mo-*

rocco"-looking "ulva;" which, forming a uniform and compactly cohering cell-tissue covered many *acres* in an unbroken continuity. A collector of Lichens would have been easily tempted to "class" this cuticle as some (more than "mammoth") *Peltigera aphthosa*, — of several town-lots' size. As in all cases of crumbling moss-spawns, its wrinkles, cracks, and crests are found efflorescent into the *chalk-white "lepra."*

The Bulbiferous Botrydium.

When exposed to the sun, the *sphærocarpus* or "mud-blister" rapidly collapses into the shape of a chemist's muffle, containing in its doublings the vivid green yolks or pellets.

The latter, soon acquiring a dense membrane of their own under the protecting scab, push a very blunt tap-root (at first resembling the tail of a "glass-tear") deeply downward into the wet soil. In this case, however, the channel of the root is continuous to the cavity of the pellet itself, while in the large or *sphærocarpus*-form it is closed. Contracted under the action of a fierce sun, the "glass-tear" pellet now forces its contents down into the root and its blunt branches, on the ends whereof as many globular, pallid *bulbs* are formed; otherwise exactly resembling the well-known radical brood-balls of the aërial roots of Hepatics. On damp grounds, the pellet itself is ultimately seen bloated into a nostoc-globule, feeding the root-balls, which now sprout forth as the well-known "rhizoclonium," or pencilled moss-velvet of ulvaceous patches, *producing the moss-bud.*

This occurs in shady, &c., localities. In sun-exposed flats, on the contrary, the pellet collapses, after forming its subterraneous brood-balls on the root-ends; and the remaining endochrome forms into *brick-red globules*, imparting a *vermilion* color to the entire extent of the grounds. The same occurs, when "euglena," set ashore, takes root as a "glass-tear" pellet. The radical bulblets often remain buried in the baked soil, to be resuscitated by some future submersion, under a shape yet to be investigated by the microscope of the rational observer.

Lepraria Kermesina.

On ploughed grounds, &c., the balloons of "sphærocarpus," — formed after rains, &c., — instead of collapsing, are seen gradually crumbling apace, from top downward, into a peripheric layer of brood-cells, thus leaving a circular apical pore or opening which

strikingly resembles a globular "theca," it is true. It is, however, not an adult or perfected plant. These brood-pellets are seen rapidly assuming the creeping, varicose growth of terraneous confervæ; and, rapidly *rounding* their cell-contents and turning red as brick, they thus form — together with the pencilled moss-velvet or "rhizoclonium" — the copious source of a general production, on mud-cracks and on ploughed fields, first of the charming emerald velvet, in foggy seasons and localities; next, of the well-known "brick-red leprosy" (the "Lepraria kermesina," or "Protococcus nivalis" of authors), in dry spells of weather.

The Atmospheric Germs.

From the brick-red phase, in all moderately damp nights, a very loose, pulverulent, and rather *ashy*-looking, molecular production — somewhat intermediate between the chalk-white and the gummous stages of the "clay-bloom" — takes place on a large scale. This very light and loosely piled *organic dust* — resembling microscopic ant-hills, so to speak — is mostly overlooked and classed as (inorganic) "dust." It is, however, present in enormous quantities, and swept into the atmosphere by the slightest breath of wind. It is thus carried all over the world, probably, and lodged on alpine heights no less than on the polar snows, as the famous "Protococcus nivalis," Ehrenberg, — filling the fields and plains, the seas and rivers, all stagnant pools and flowing springs, with a really immeasurably numerous supply of its subtlest germs — of only the four-thousandth part of a line in bulk.

The Gum of the Land. Peat-Bogs.

It would appear appropriate to remark that the *ubiquitous* silver-moss, whose spawns occupy the greater part of all open clayey grounds and fertile plains, — aside from most transient mud-water collections, — only scantily fructifies in the adult state, compared with other mosses. It naturally occupies the adobe-like, baking, clayey grounds, the fertility of which it seriously affects; whether by forming an impenetrable gummy cover, impervious to the sudden and beating storms of our summers (not having *time to re-soak*, leaving the water to rush off, and the ground dry underneath), or whether it otherwise act as a *true discutient and fallower of the soil* as a solvent of silica and iron. On rich ground, more favorable to moss-development in general, it is apt to be crowded out by the stronger races. It is thus that each permanent lagoon — even the

bilge-water, *e.g.*, of a wharf-boat, as quoted above — is mostly occupied by a single dominant moss-vegetation. In the latter case I had occasion to observe a Hypnum as the adult moss, its "zygnema" or spirally ornamented, quill-like water-floss, remarkable for the great number of parallel coils of chlorophyl; while in peat-bogs the Sphagnum's phases seem to prevail, yet not to the exclusion of about fifty species of various genera of mosses which are enumerated as inhabiting, *e.g.*, the peat-bogs of Austria. In the famous Plattensee, a single confervaceous type seems to domineer the whole to the exclusion of others; and the radiating development of its fibres into floating balls has been accurately described in a special monograph.

The Zygnema Quill.

Having considered the moss-spawns of the dry clay, the damp soil, the mire, and the atmosphere, I return to the mud-blister, as a connecting point of departure for their aquatic developments.

When submerged, *e.g.*, by rains, the "sphærocarpus"-balloon or vesicle bursts, and emits both its molecular chlorophyl and its glairy-zoned, 2–5 pellets.

The molecular discharge presently, by cross-segmentation, forms into a closely effused, very dark and glossy "nostoc," the single beadlets of which at once, by elongation and internal nummiform division, directly grow into the verdigris-colored "oscillaria" fibrils, *in the course of a few hours.*

The "Sphærocarpus" pellets, disgorged by the bursting of the balloon, can be found, *e.g.* immediately after a thunder-storm at the bottom of inundated flats.

The yolks or pellets at first are found unaltered, but in a few hours are seen cross-septated by a pellucid sheet; while the gelatinous envelope is condensing into a cell-coat, and the contents have a pallid, punctuated, uniform appearance. As many as four to a dozen of cross-divisions are thus formed, — always continuing in the immediate calibre of the pellet, — after which all the subsequent partitions are formed with the charming *spiral arrangement* of an emerald chlorophyl, that characterizes the *pseudo*-genera "Zygnema" and "Spyrogyra." I have not yet been able to ascertain whether the *new* additions are thus engendered, or whether the previously medullary-punctuated contents are thus changed,— in the *older* parts. The former is, however, the more probable.

The "zygnema"-quill is the most bulky of all these fibres, and of equal width throughout. It is thus distinct from "Spirogyra," which is tapering. Both never ramify, but are very apt to cross-divide into their drum-shaped component sections, and directly elongate, rounding off their flat top-ends. I have never seen either of these types procreated from any other source, or "spore," than the one here given, save a bluntly crescented juvenile form.

As for the origin of the (tapering) "spirogyra" quills, which form ledges as of clotted hair-locks on the borders of springs and glades, the probability is that, in the first place, they can arise from the drum-shaped segregative segments of "zygnema;" since the latter continue to reproduce cells, elongating in the axial sense. In a juvenile, few-jointed "spirogyra," the oldest or butt end is invariably the bulkiest, and as thick as a zygnema drum-cell. These lustrous, lubricated, and spirally ornamented "quills" are seen rising with their butt-ends somewhat above the water's edge, as, *e.g.*, on a tumbler's side or the walls of springs. When rising upon the mud of the shallower parts of springy glades, they are seen to deliquesce from the rear, cell by cell, into a voluminous "nostoc," or rosary-beaded gelatine of dark olivaceous color. On subsiding glades, red with vermilion euglena scums, and emerald with the clotted spirogyra hair-locks, the latter are found sticking to the half-submerged grasses, and, when laid dry by subsidence, form into blackish webs and crusts of exsiccated "nostoc," crumbling on the grass-stalks.

Spirogyra.

I must here refer to De Bary's publications concerning these forms. Judging from his figures, there can be no doubt that a "spirogyra," &c., joint emerged from some rounded *cylindric*, harshly coated cell. He calls it a "spore." Well. He also sees "spores" formed by copulation of spirogyra fibres, in the well-known fashion. His idea is, that the copulative "spores" would then produce the copulating quills; but the evidence is defective. The experiment ceases with the production of some spore or other, and neither their identity with those crusty ones which produced the spirogyra, nor the capability of the copulative spore of doing it, is experimentally demonstrated. That proof is actually missing, in this and most of his published observations respecting "desmidiaceous" or "palmellaceous" cell-broods; thus leaving a fatal break in the observation and in the argument alike.

Zygnema Copulation.

By innumerable observations, conducted on the largest scale by watching the wholesale changes as they occur in nature, I am enabled to state, that the *bead* or "spore" formed by the well-known side-wise and mutual transfusion of contents, in the "copulation of Zygnema" (by *inosculative warts* formed on the single joints) is an oval, or ellipsoidal, green, *coatless protoplasm*. As the bulky membrane of the progenitorial fibre spontaneously deliquesces into a very voluminous soluble jelly, a great many of these beads assume the bright "venetian-red" color which marks their presence when floating on the surface of swamps. They now, however, constitute the famous *pseudo*-genus "Euglena" of Ehrenberg: one of the so-called "*flagellate infusoria*" *par excellence*.

The Euglena.

This "Euglena" is a *contractile vegetable protoplasm body*, generated from a plant, and as a plant, and returns into a *moss*. Feeding without a mouth or entrails, it is rather organized in strict likeness of all spermoid elements, whether of animals, cryptogams, or pollen-discharges. It is a coatless, *flagellate* cell, itself; but *not a* "*sexual*" *semen* (incapable of independent development).

The *euglena*-phase is indeed the most important and instructive one to be studied, of all these physiological forms; on account of the multifarious processes and developments it can conditionally assume.

It mostly forms the uniform red or vivid green, glairy cuticles on still pools and gutters. Its grub or leech-like *writhing sarcode-bodies* are about $\frac{1}{40}$ of a line in length, oblong-fusiform, with a clear, pointed rear, and a blunt, clear fore-end. The latter has a slight prolongation like a neck, bearing a rounding or "head," with apparently one red eye, and a little groove like a mouth, from which propends a long, delicate, filiform, vibratory *flagellum*, rather longer than the body, so to speak, and in its earlier stages carried backward along the body while being propelled forward.

The flagellum is rarely discernible even with a 500 diameter magnifying power. Only at a later period, when the incessantly contracting or writhing body turns colorless, the flagellum becomes visible, stiffish, and porrected, travelling ahead of the body, which is now rather tapering in front and sac-like, blunted at the rear; while every one of its (no longer green, but partly red) con-

stituent particles seems to be active with independent contractions. The presence of its discernible "Chinese pig-tail" or apparent proboscis (frequently rolled and unrolled like the spiral proboscis of a butterfly, or plied like a horse-whip, with a fluttering tremulous tip), alone suffices to distinguish it in this its pallid state from the slowly crawling "sacs," and pseudo podial stars, of the "*amœba*" or vorticello-planarian pellets.* The flagellum is finally shed, and under the very microscope seen to dissect into *rigid jointlets*, — like some insects' antennæ. The joints, increasing in size, shove into zigzags, and finally separate, spontaneously moving, as some individual "diatomaceous" form.

On calm, sunny days the Euglena covers still pools as a dense mosaic of ovally contracted beads. The "heads" are hid, by apical introversion, while they stand erect, with blunt-intracted rear end about ¼ immersed, — like so many eggs in salt — into a hyaline, gelatinous stratum. When touched with water, the whole body at once resumes its active contractions and dreamy gyrations; and the empty *sockets* represent a close and hexagonal arrangement as of a honey-comb with triangular "intercellular" abutments. This process may be repeated until, at last, the whole bead becomes either "encysted" (as a coated "cell"); or (in the dark) it fades into an extremely voluble pallid body resembling an amœba, and dissolving into colorless automatous molecules.

The "euglena" or peristaltic protoplasm beadlet preserves distinctive features in different mosses. That derived from and issuing into Funaria is more pointed at the rear, and frequently contracts into the shape of a wheel and axle, lustily spinning round, like a top made of a button. The euglena of the common silver-moss does not behave in a like manner.

Its Germinal Matter.

The red or green *euglena* which resulted from the copulation of *zygnema*, when drifted upon the mire heated by the sun, within a few hours disintegrates, as do all other euglenas, into its component chlorophyl (or miniate-colored "erythrophyl") particles; the larger whereof immediately commence lengthening in the axial sense, turning glassy pale in this first stage of "oscillarian" existence, while assuming the cross-bars and automatous lengthwise locomotion of all free "oscillaria"-fibrils. They now gradu-

* Amer. Journ. Sci. and Art, No. 8, 1871, p. 95.

ally assume the dusky verdigris hue which is so characteristic of the oscillaria-fibrils.

Naviculæ.

Along with these primitive oscillaria-molecules, about $\frac{1}{1000}$ of a line diameter, quite a number of most minute, spicular slivers or "naviculæ" are seen darting out from the euglena-pulp of miscellaneous ingredients. These siliceous shuttles, soon increasing in size, form perfect *naviculæ* (*pseudo*-genus "Navicula," &c.); and so do likewise the joints of the stiffened flagelli, after the latter have been shed (as when, by privation of light, &c., the "euglena" has faded and become "amœboid"—see above). The most frequent production of "naviculæ," however (or of the allied *pseudo*-genera),* can be watched growing under the microscope, when from some confervaceous mass the contents are forcibly crushed out, in a suitable fixture (compressed between glass-slips, somewhat held apart, wired together with thin copper-wire, and preserved from exsiccation, *e.g.*, under an inverted tumbler, while yet accessible to strong daylight, and the surrounding air enclosed with it). A great many of the component granules will each lengthen out into a straight body, resembling, *e.g.*, the mericarp of umbelliferous plants; or such "desmidiaceous" cells will form *within the intact fibre* itself. They will also form as *stipes*, which branch by fission, &c. They then multiply by fission, as is well known; not exclusive, however, of a *great many* other methods of propagation. The silica-coated shuttles, shoving along all the while, at certain seasons (in fall) produce such an enormous amount of green molecules, extruded by their nozzles, so to speak, that they form clots of *whitish green "curds,"*† floating all over the surface of "sink-holes," &c., and in vast quantities deposited along the beach. Such molecules may frequently be watched moving in the long axis of a "navicula" and then being expelled. On the beach they readily luxuriate into a dense crop of "glass-tear" blisters.

The *minimal naviculæ*, expelled from the deliquescent "euglena" (when mired upon a beach in the sun), are also frequently seen

* "*Mastogloia Smithii*, [*M. lanceolata* and *Schizonema Grevillei*" (Carp. Micr. pp. 302, 303), are the *contents of* "*Confervaceæ.*"

† A similar whitish-green, paint-like color is frequently observed, when, after prolonged droughts, a gentle rain falls. All street gutters, stones, and wood adjacent to the streamlets of the rain, are as it were stained with a light verdigris. This appears to result from the pulverulent proliferations of the "brick-red" leprosy, or "lepraria kermesina" (abv.).

parting in the middle by producing a globular bead; while still the wedge-shaped ends adhere. By the common mode of chlorophyl-production, this bead develops into an entire "nostoc" fibre, still bearing the navicula *prows* at either extremity. These locomotor fibres thus afford a very handsome and instructive appearance; a larger bead relieving the uniformity of smaller ones at regular intervals, as in a *rosary*. At the spontaneous separation of these beads, whether small or large, both kinds directly lengthen out into simple oscillaria fibrils, as in all cases of bryaceous "nostocs."

The gelatinous, dreamily contracting, gyrating, and wandering, mouth- and food-less *euglena*-sarcode presents two features which it has in common with the large, crescented, desmoid cell called (*pseudo*-genus) "Closterium." It has a red cell-nucleus or "eye," the component vibrios whereof cannot, however, be separately distinguished, nor do they apparently travel or circulate, as in the case of the "closterium" (or fusiform-crescented) cell phase. Both alike, however, are occasionally seen to extrude "germinal molecules" (that *universal semen of the cell-tissues*) much in the fashion of fæces; and the old mistake of claiming it as an "animal" appears very pardonable, from this feature alone.

The Euglena as a Moss.

Aside from its indirect origination from the *sphærocarpus*-pellet, which, like that of "conferva" and the "glœocapsa"-pellet directly issues into the *bryoid phase*, or perfect condition, the most decisive feature in the entire euglena development, as to its nature or proper classification, is this: that when drifted upon a moderately dry and cool or shady beach, the "euglena" bead, standing erect and packed in its basal slime — as above — at once *assumes a cell-coat and casts a tap-root downward like the secondary (i.e., "glass-tear") mud-blister: forming radical brood-balls, and sprouting the pencilled moss-velvet which bears the moss-bud, as true "rhizoclonium."*

We have here arrived at its ultimate "*adult*" *stage*.

The Water-Flannel.

Aside from their slimy diffluence, the red euglenas, sprung from zygnema-copulation, when occasionally found settling on *shady* sites along the beach, becoming more and more contracted, are seen gradually shrinking into certain crisp, brownish, globular beads, which subsequently turn of a grayish-black color.

These again, on absorbing moisture — when after rain the water

rises upon them — swell up to the fivefold diameter, and after dissolving their outer strata into a gray molecular slime, composed of the most minute motile elements, globules, shuttles, spicules, &c., their interior exhibits a few *meshes of the famous "Hydrodictyon"* or water-flannel; the origin and mode of propagation whereof had hitherto remained essentially unexplored. They are hard to disengage without fracturing their connections, but evidently occupy the centre, as about one dozen of primitive meshes cohering in a somewhat hexagonal shape, and tightly surrounding a tourmaline-colored, more or less rosetted, central nucleus. From the mode in which these joints or meshes cohere and tear apart, it is to be surmised that they form a scalenohedron, of twelve bars, meeting by threes at each junction, and thus encompassing the nucleus; as twelve globes surround a central one, thirteen in all.

The joints here are about $\frac{1}{100}$ of a line in length. The full-sized water-flannel "nets" or "fillet-purses" are about 6 inches long by $1\frac{1}{2}$ wide, and form green reticules with meshes about $\frac{1}{10}$ of an inch wide. The joints mostly meet by threes, forming mostly pentagonal meshes. Their well-known endogenetic production of *new reticules inside of each joint* has often been commented upon by authors. It has also been discovered, that at certain times they discharge "androspores" (*sic*). The "sexual" and "adult" nature of the water-flannel was hence proclaimed; without any indication whatever of its *origin* and *end!*

At first, the joints are roughish-dotted and darkly green. Drifting upon the waters, several of the "hydrodictyon's" joints swell disproportionately; their confining membrane becoming of a thickish, gelatinous nature, and vivid-green cell-nuclei appearing attached to its inner surface.

When the bar remains intact, these nuclei subsequently join into meshes; each nucleus forming the *centre* of a node. When ruptured by drifting, wind, or the pattering rain, &c., the cell-nuclei, heretofore motionless, at the instant the water touches them, break loose from their station, and violently vibrating start forth like a swarm of bees. They taint the water with a sort of olivaceous straw-color (or like flowers of sulphur), and attaching themselves to straws and rocks, &c., "suck" fast, as it were, by the vibratile end forming a sort of disc, with a neck to it; while the rear end grows ahead by cross-septation into equal, cylindric joints. The latter are occasionally relieved by larger blackish or dusky ones, some of which ultimately swell into tourmaline-colored

globes of a double contour. In this condition it is known and figured as (*pseudo*-genus) "Œdogonium."

A few observations on the ulterior processes of its growth we owe to Pringsheim, — naturally under the favorite bias of "sexual" organization. At certain seasons the ponds, after having been substantially filled up with this water-flannel, which can be hauled out by the armful, straining the clear water through like a sieve, are occasionally found all at once free from any apparent vegetation of this kind. An immense amount of vegetable and corruptible gelatine has substantially dissolved in this water, tainted with a flattish taste and smell, and productive of malarious fevers. The process of spontaneous physiological dissolution, of all "Confervaceæ," mostly proceeding from the rear end, is the great source of such water infection.

Vaucheria Copulation.

Another most remarkable development of "euglena" is that into so-called "Vaucheria," by direct elongation and amplification, *in its sarcode condition;* writhing with that screw-like twist which is so remarkable in its lanceolate-pointed, its warped-wafer-shaped *samaroid*, and its pyriform-*charoid* transmutations known as "E. longicauda, E. Pyrum," &c., likewise. (All these transitions can be watched, *e.g.*, in stone or china-vessels, taking place within a few days). When forming into Vaucheria, as observed by myself, in fall (on a tub buried in the ground to serve as a pond), the green sarcode body is seen to contain vacuole-like, *joist*-shaped bodies, resembling blunt "desmidiaceous" frustules ("Pinnularia," &c.), moving backward and forward by its contractions. It afterwards assumes a uniform tubular form as if of blown glass, unseptated, bulbous, crooked and ramifying in equal calibre.

Many of its branches now produce a compound organ of transfusion or copulation, very much like the spores of the Equisetum or scouring-rush, and those of "Characeæ;" with this difference, mainly, that the curved tubuli, arranged around a central vesicular body, here stand apart, as horns or prongs, and are not twisted around it.

In the case of "Vaucheria" these horns, often in whorls, are incurved and septated near the top. Their well-known discharge of germinal or vibrionic matter upon the vesicle, I have likewise fully observed. *Without an apparent opening* in the membrane of the lemon-shaped vesicle, the dark-green contents of the latter at

once commence violently rotating, *in a mass*, around the longer axis, continuing for many minutes in this stately, as it were, "planetary" motion. .

The vesicle thereupon enlarges, and finally separates from its macerating mother fibre. It immediately throws out branches, repeating the same "vaucheria" developments. Its organs are partly found singly sessile on the fibre, partly — *on the same stem* — pedunculate and clustered in a whorled capitulum. Preserved in glycerine, the "capsules" acquire a double or triple internal confine, so as to afford an altogether different appearance. Some vaucheria-fibres are studded with bulbous moss-buds, — as prothallia. Some bear pyriform-clavate apical *joints* containing a large pellet, &c., and their endochrome turns into slim flint-spicules.

Primary Euglena.

The usual primitive and most massive production of the euglena-phase itself is this. After the last frosts, the "clay-bloom," &c., washed into water-collections, at once commences developing into the chlamydococcus-broods (or colostriform "volvoces," in other cases).

The chlamydococcus beads macerate their membranes at every ensuing spontaneous bi-quadri-octonary dissection, repeating the old form through several generations. It is in this condition that it partly also falls a prey to an internal "vorticellan" parasite, — which I have described in "American Journal of Science and Art," No. 7, July, 1871, p. 22 — and also to another *external* one, probably belonging to the same vorticello-planarian Infusoria.

The cell appears surrounded as with pin-heads, distantly stuck into it, as into a pin-cushion, by some invisible connection or proboscis.

This appearance has no doubt given rise to the original diagnostic creature called "Acineta." The cell perishes, and the parasites I have not yet traced.

After repeated self-dissections of the flagellate-roving "chlamydococcus," or the puriform "volvocine" beads, a final production turns out ellipsoidal; revolving on the long axis while dashing forward, and with a clear "polar zone" or spot destitute of chlorophyl granules. After a while, their membrane macerates, and they adhere, *e.g.*, upon a glass slip, with a pointed rear end; and, being now green all over, the body engages in the *throe-like* writhings as of "euglena," while the cell coat dissolves.

The chlorophyl soon arranges more around the middle, leaving

both ends clear. In a short time the cells appear as true "euglenas," with clear ends and a red "eye."

Another — later — formation of "euglena" is the following, by

Vibrionic Agency.

On breaks in dense oscillaria floes which cover stagnant waters, a sort of brittlish scum-cuticle is formed; partly composed of writhing red-eyed "euglenas," and smaller, purely green ones; partly of smaller dark-green pellets endowed with an albumen zone. They are of the size of glœocapsa daughter-cells, and, no doubt, are the enlarged sections of dissolving oscillaria fibrils. These yolk-like beadlets are mostly quite inert and motionless, but on being "seized upon" by apparently a single globular, minimal vibrio, appearing in profile as a violently agitated, vibratory molecule about $\frac{1}{4000}$ line in bulk, are then seen violently rotating as if *hustled around* by the invading particle. As the latter disappears within, the cell again becomes inert, but after a few seconds an internal commotion — as in a bee-hive — is seen created in the dark chlorophyl centre of the cell. Each individual punctiform particle of chlorophyl now starts into vibratile action; and, cohering under the albuminous zone's surface, the whole bead begins to writhe as "Euglena," although destitute, at first, of the clear end and red "eye." In a few hours the whole production appears as complete "euglena."

The first (or earliest) euglena-scums are thus formed of the so-called "Chlamydococcus pluvialis," &c., and the first *oscillaria*-scums arise from *euglena* in the following manner.

When drifted upon the sweltering mire, all generations of "euglena" behave as above detailed, dissolving into the primitive "oscillaria," "navicula," "nostoc," &c., molecules.

Euglena Encystment.

If left afloat, they rapidly "encyst" standing on end, by acquiring a cell-coat or rigid membrane. The supporting glairy cuticle dissolves, and they settle at the bottom of the puddle as immovable, now rather oval or ellipsoidal, "still Protococcus," so-called. They now rapidly dissolve into a uniform molecular pulp of (*colorless*) primitive "oscillaria," &c., frustules — as in the above cases.

Oscillaria Pulp.

The gases exhaled under the action of the sun soon buoy up these grumose rugs of molecules interlaced with developing os-

cillaria sprigs as with a thousand minute knitting-needles. At night, they mostly settle to the ground again. By a repetition of this process, the whole pulp gradually acquires the uniform character of the blackish, lubricated, and often inflated froth not only covering flat ponds, but also generated at the bottom of any sluggish little stream, in summer. Immense quantities of this confervaceous gelatine is thus seen buoyed up in drains and sewers, or in creeks, and then conveyed into the larger water-courses, where they naturally dissolve into slime or liquid gum.

There are, however, a great variety of other euglena encystments.

Euglena Pyrum, Ehrb., &c.

As above indicated, a uniform brood of euglena, when kept, *e.g.*, in a china dish, will in a short time produce a great variety of "still" cell-forms, miscellaneously. One of frequent occurrence is a samaroid one resembling a ripe "elm-seed," notched or cordate-orbicular, flat, with a long acuminate "tail," a central nucleus, and longitudinal striæ, — as above mentioned, — the striking prototype both of the epithelia of the mouth of human anatomy and the scales of butterflies' wings, &c. Another variety, also containing and showing oblong "desmidious" bodies within, takes a longitudinal, samara-like development, but mostly falciform-twisted and with an uncinate "head," while others appear pear-shaped, with a system of finely denticulate screw-lines, of a fine "thread" enveloping the whole surface, and terminating in a coronet, which recalls the characeous seed-formation, on a microscopic scale.

Closterium.

A very frequent transmutation is that into certain varieties of so-called (*pseudo*-genus) "Closterium." Assuming a semilunar fusiform shape, and acquiring a rigid surface, a small size "closterium" is formed. Gradually the "tail-end" likewise forms a few motile granules, as a red eye, into a nucleus. There are a great many varieties of forms, of various origin and varying with the seasons. Some are very long and almost straight, longitudinally striate, with a series of rosulated pellets in the long axis, cross-divided in the middle, and with a large clear space at either end; others are very slim and semicircular-crescented, &c.

In each of the clear terminal spaces, there is a so-called cell-nucleus, of a sort of "garnet" color.

Red Vibrionic Nucleus.

A close inspection *in vivo*, and in all directions and positions, has shown me, that these globular red nuclei (or "red eyes," Ehrb.), frequently consist of moving particles, free to roam among each other within a clear globular cavity, itself contained within the surrounding clear substance. Further observations (also demonstrated to a microscopist's class, at St. Louis, Mo.) prove that they contain clear vibrionic globules, about $\frac{1}{4000}$ of a line in bulk, and provided with a flagellatory or at least a "flickering" organ, not otherwise visible than by its action and the varying *red flashes* it gives.

These flashing "germinal" molecules are seen hived in the globular cavity, as in a focus, but can readily be observed *leaving and entering and coursing lengthwise through the entire cell*, even across its "equatorial" line, and returning to the focus. Such is the usual occurrence with *all* protoplasm "streams"—(*i.e.*, *travelling particles*) — which course around and meet and cross each other in the so-called "nucleus" of growing cells. In the adult cells, as, *e.g.*, the epithelial ones of Cyanotis zebrina and others, the original constitution of the cell-nucleus, consisting of about a dozen affixed "vibrionic" particles, can be easily detected.

These "nucleolar" particles being *red* in "closterium" cells, they are quite conspicuous *coursing* along over the green substance, when they appear as very dark points, on account of the complementary colors involved.

Closterium Progenies.

When allowed to fade in dark vessels, all the axial so-called nuclei or rosetted pellets are seen clearing up and dissolving into countless swarms of now *colorless* vibrios (or vibratile molecules) leaving the cell through its apparently intact, clear ends. The same is observable in certain very delicate straight fibres — (some nondescript "Oscillaria" or "Lyngbya," &c., &c.) — formed inside the "closterium" itself, and leaving the active cell, with nuclei still operative, without any "serious consequences," apparently.

"Closteriums" are partly straightish, partly strongly curved or crescented; some thicker in the middle and escarped at the ends.

They are known to multiply by cross-division; the "equatorial" break readily healing over with a new tusk or lunar horn.

They are likewise known to copulate, by *crosswise* transfusion at

their equator, as I have ascertained in certain cases. This process leaves all four horns behind as empty scabbards, — tilted backwards. The bead produced, and claimed by De Bary, &c., as "*the* spore of Closterium" is not semilunar, but globular and kidney-like-lobulate, like a compressed cluster of grapes, or a *chlamydococcus* in process of multisection.

What next becomes of it (probably a "volvox" or "uvella") I have not yet had a chance to ascertain.

A very frequent development of "closterium"-cells is the following. In flat rain-pools, or tanks, frozen through winter, and in the preceding fall, either newly formed, or replete, *e.g.*, with "vaucheria," we often find under the thawing ice, in spring, a flaky mass as dark in color as oscillaria. It consists *exclusively* of "closterium." If beached, and deliquescent on the mire, its component chlorophyl molecules at once start into the oscillaria (black slime) development. When stuck in the mire *under* water, the cell, enormously swelling both in length and width, forms what would be called a very large (*pseudo*-genus) "Microcoleus," or *lumbricoid cell-hose replete with* (*ps.* g.) "*Oscillaria.*" In this case, however, the hose, naturally parting in the "mid-girth" thereof, represents two very long scabbards, or quivers, wherefrom fascicles of oscillaria wires are seen slowly prorepent; a feature belonging to the diagnose of the "Genus" — *one genus harboring the other!*

The Mulberry-Shaped Rotaries.

The crescented closterium cells, which are left suspended in the tepid mud-water, very soon develop their axial beads into compound (or acinoid-conglobated) rosulated, twirling or revolving cell-bodies, without a confine, but enveloped in a clear gelatinous zone, called a "*lorica*" (*sic*) by Ehrenberg. They can be "classed" — *ad libitum* — under the pseudonymous heads of either "Volvox," "Uvella," "Polytoma," "Glenomorium," "Pandorina," "Syncrypta," "Uroglena," or "Eudorina," of titular lore. When first liberated, they already exhibit a composition of similarly compound granules, which are evolved in successive generations, by spontaneous segregation. They finally, however, present a composition of indivisible, somewhat wedge-shaped and angular granules, about twenty-one in number, and rather sparsely implanted into the connecting slime-body (or "lorica"). In this shape, when crushed apart, they at once assume a very rapid spontaneous locomotion at the small end (originally turned toward the common centre;

whereas the original compound body itself revolves all around by some imperceptible (perhaps reflexed)flagelli or "cilia."

Œdogonium.

When left to develop, they assume a delicate confine, and settling down develop their solitary nuclei into juvenile, one or several-jointed "œdogonium" cells; which, when liberated, at once take to roving around with great activity, but soon subside on some suitable object to develop into the same sulphureous floss as the liberated nuclei of the fillet-purses, when their mother joint is prematurely ruptured. A similar "œdogonium" fleece is generated from the red conferva-pellets, as we have seen before; and they may stand as an aquatic homologue to the disjointive moss-velvet or "rhizoclonium," and the latter as a terraneous "œdogonium" form.

Anthophysa.

Among the "acinoid" (or rosulated) revolving beads, we must here notice the famous "Anthophysa Mülleri;" for which "a separate kingdom" has been likewise prepared (Nov. Act. Nat. Curios. 1854, vol. i., tab. xv.) It consists of a raspberry-like conglobation of clear, oval beads, violently spinning round as a whole, on top of a somewhat spiral, brownish, and aciculated fibre, tapering toward the evanescent top whereon the clear "uvella" struggles to free itself. These fibres are formed, where "spirogyra" quills are dissolving, from the straightening spirals of the latter, loosened from the macerated "spirogyra's" confining cell walls. After a short time the *uvella* (formerly a cell-nucleus of "spirogyra") twirls itself loose, and the constituent beads gradually separate, assuming a virescent color, and thenceforward follow the developments conformable to "fresh-water algæ."

Sphæroplea.

As for the so-called "volvocine" or naked, compound (rosulated) revolving cells, exactly the same kind as produced from "closterium" are occasionally formed not only in the lateral warts of the common water-hemp, but they are likewise found copiously preformed in otherwise clear, but intact and connected, joints of the fillet-purses ("hydrodictyon"); all their chlorophyl having apparently undergone this change. The same may be said of cer-

tain fibres called (*pseudo*-genus) "Sphæroplea;" where they are arranged in the interior in an alternate series. In the natural process of spontaneous maceration from the rear forward, all such contents are set free.

Chætophora.

Similar rosulated cell-beads are formed in the segregative joints of the *pseudo*-genus "Chætophora." The origin of the latter takes place in various modes. The most frequent one is, as far as aquaria, &c., are concerned, that certain short frustules of broken "oscillaria"-spriglets are seen a little flattened out in the fashion of a ruler. Upon breaking or spontaneously dissecting, the fracture now exhibits two distinct, although minute, horns or claws, like ox-horns, at either end.

Such frustules, when watched and bred, both in their natural abodes (or "*habitats*") and under artificial circumstances, are seen macerating their membrane while displaying a double series of claw-shaped beadlets, — blunt-end inside and arranged in alternating order; thus forming a sort of double comb with uncinate teeth.

As the confine macerates, each single one of these beadlets grows directly into the clustered ramifications of awl-shaped, jointed branches, the setiform empty tips whereof afterwards almost hide all appearance of verdure, and appear like milky flakes of slime, in spring-courses and cow-tracks, in wet places. They are seen rapidly segmenting, the chlorophyl of their elongated joints centrally contracted into beautiful *rosulæ*, while the blunt top of the tuftlet produces some inflated joint, forming a tessellated bead, — breaking up into more Chætophora.

At first, the primitive claw-shaped body detaches on its blunt end a globular bead which (in aquaria, &c.,) serves as a centre of radiation of "chætophora" upon the glass.

Draparnaldia.

Afterwards some immense roving-beads, about $\frac{1}{40}$ line diameter, are found booming in the water, very globiform, dark-green, smooth, and with a clear navel-point, so to speak, whence proceeds their rapid flagellatory motion. They can be readily observed attaching themselves to any immersed glass-slip, &c., fastening as by a suction-disc at the "navel"-end. By a rapid rearward elongation and septation, they produce a confervoid fibre, with [redacted] or barrel shaped joints; several of which are thick-

ened and of a very dark-brown color. They now are called (*pseudo*-genus) "Draparnaldia;" and their subverticillate, tufted, setiform branches constitute the "chætophora," with axial top-beads.

The smaller "chætophora" form is also observable in many cases of the mud-blisters ("sphærocarpus"), neither crumbling, deliquescing, collapsing, nor producing a moss-bud; when the endochrome is seen prorumpent as tufts of a very short-pointed "chætophora." The same likewise arises out of a certain bullate inflation (resembling the euglena, &c., "glass-tear") of the joints of primitive hydrodictyon; when the buried net-work is not submerged, but still drenched by dews, &c. The "nuclei" contained in such an inflation (which very much resembles a chemist's retort), turning of a bright green, directly produce the same fascicular and pointed, short "chætophora"-velvet.

Endochrome Forms.

It will be readily observed that the contents or endochrome of the confervoid fibres, more particularly, are direct commencements of "*desmidiaceous*" forms. The ultimate development of a great variety of "hibernating" or *storage* cells has yet to be explored. We find the endochrome of short "zygnema" frequently condensed into a clear, gravelly, *chondroid* substance (resembling the "goitre"-cells). When life revives, in spring, we find shapeless slivers of a clear chondroid or quartz-like substance swelling and giving forth innumerable germs of the "protococcus" and "chlamydococcus" description. In permanent sink-holes, &c., I find the first and uniform production, in spring, to consist of a gelatinous mass of small globular beads, about $\frac{1}{400}$ line diameter, imbedded in an ample amount of a hyaline jelly. These globules rapidly multiply by dissecting in the (desmidiaceous) fashion of "split pease." The same is produced by a gelatinous spirogyra-dissolution, studded with "naviculæ;" the beads eventually *escaping as "euglenas."*

Desmidiaceæ.

As for "desmidiaceous" and "palmallaceous" forms, they are rather scanty on clayey soils, and in the more transient, stagnant water-collections.

In spring, under the ice, a uniform production of "Closterium Lunula" appeared in a flat dell of a deep clay-excavation; the same in a permanently watered wash-tub, set into the ground as a

garden aquarium. What becomes of the product of the crosswise "closterium"-copulation, remains yet to be investigated.

A most significant wholesale development of "baccillaria" I had occasion to examine on the shaggy oscillaria-coatings of the St. Louis lower (old) reservoir; containing a supply of very pure, strained water, derived from the elevated distributing reservoir. It abounds with fish, and the only moss-spawns there visible are a brownish-green, flaky coating of its stone walls.

On inspection, they were found to consist of rather rigid "oscillaria" fibres, flattened out, ruler-like, and engaged in process of self-division into the silica-coated, shuttle-shaped cells, which in this sidewise connection are classified as *pseudo*-genus "Baccillaria," &c., &c.

Concerning other so-called "Diatomaceæ," "Desmidiaceæ," and "Palmellaceæ," &c., I will here remark, that, among the comparatively few forms usually occurring in clayey soils and ponds, the (conjugately bicordate, brooch-like)

"*Cosmarium Botrytis*"

is perhaps the most frequently met with. The aciculated or prickly globules, called "Xanthidium" (and resulting from the observed copulation of *cosmarium*, &c., cells) I have not yet had occasion to observe personally. What their ulterior *development* is, the discoverers perhaps did not think it requisite to investigate, before classifying them. Of this "cosmarium," however, a great many different endochrome evolutions can be likewise observed. In the first place it seems to be directly formed, *e.g.*, by incidental aqueous separation of the primitive bud-cells of conferva-pellets (abv.), and within the endochrome of "zygnema." Some of them have a reticulated interior, liberating a set of green or mustard-seed-colored, globular cells, — ulterior fate yet to be explored, — while the remaining *stellate-cratiform* intercellular frame is often found relieved, exactly in the shape of the graceful revolving tablets, resembling our ornamental tripods for flat-irons, and known as

Pediastrum Granulatum.

Its various shapes and modes of self-reproduction, by segregation of its swallow-tailed frustules, are figured in all illustrated handbooks. As to its first origination, that from "cosmarium botrytis"

is not improbable, considering the prevalence of reticular intercellular tissue-genesis, generally speaking.

A similar and most interesting form is the one called

Gonium.

A tabulate interrupted-work consisting of sixteen beads — or even of so many *small* "goniums;" four in a square, each topped-off by a *pair*, and the four lateral interstices taken up by as many of the same kind. In others, the beads are round-oval, like chlamydococcus, each provided with a flagellum twice or three times its own length, and altogether the most conspicuous of all.*

Bracelet Lyngbya.

In some cases, the entire extent of, *e.g.*, a large sink-hole, or of a submerged town-lot, &c., can be found uniformly filled with a single stage of cell-productions. I have thus noticed a delicate dark-green, brittlish, long-jointed variety ("Lyngbya"? "Calothrix"?) of "oscillaria" type; and in others found a huge production of similar ones, each fibril rolled up in the shape of a double bracelet — as it were — with a large ellipsoidal cell at one extremity, thus forming the brooch of the bracelet or the signet of a ring.

Innumerable forms of cell-ingredients, of these and the analogous and homologous germ-phases of thousands of true species of mosses, remain yet to be traced in their logical connection both of substance and phenomena. What nobler scientific stimulus, indeed, could be offered to the eager lover of microscopic investigations, than to watch all these developments under their natural conditions; with the laudable object of a thorough identification, and expurgation of the thousands of imaginary "species" and faulty "genera" contained in our repositories?

* The following is Ehrenberg's description of this his — "18th genus, *Gonium*. Eyeless and tailless; a simple carapace; spontaneous division into applanated square polyparies. 72d sp. *Gonium pectorale*. Green corpuscles, enclosed (?) within a crystalline carapace; polyparies $\frac{1}{48}$ — $\frac{1}{12}$ m.m., applanated, square, formed of sixteen animalcules of $\frac{1}{192}$ — $\frac{1}{48}$ m.m. *Habitat*: Copenhagen, Mietau, Quedlinburg, Dessau, Berlin, Linz, Paris, northern coasts of France. Pectoralina Hebraïca." It is evident that each *term*, if not purely descriptive, involves a subjective theory; in this case so many foregone conclusions. Eyes, tails, a carapace, polyparies, animalcules, are so many unsubstantiated postulates, *à priori*. The majority of these creatures are evidently addicted to European capitals.

3. The Organic Identity of the Albumen and Endopleura of all the Phanerogamæ. By T. C. Hilgard, of St. Louis, Missouri.

All seeds of the flowering plants (the net-leaved, blade-leaved and the pine tribes) are collectively described as consisting of a *germ* or "embryo," enclosed within *two separate seed-coats.*

A great many seeds, like those of the mustard, nasturtium, buck-eye, bladder-nut, the ailanthus, sumach, china-tree, orange, camellia; the gum-pod ("gumbo"), hibiscus, the cocoa-bean, almond, pea and rose tribes, the brazil-nut, walnut, chestnut; the cockle-bur, sun-flower, and melon, — all conform to this description, and the natural tribes to which they belong form a connected region of the flowering plants, generally speaking.

It is likewise understood that a great many seeds have their germ proper imbedded in a bulky, nutritive lump called the "*albumen*;" which thus forms the main bulk of the seed, *e.g.*, of the ivory-nut, the date-kernel, the cocoa-nut, the pepper, paw-paw, and nutmeg, and all the grains no less than the well-known coffee-bean. In water, the latter will swell and protrude its stubble-like embryo out of one end of its horny, enveloping mass, or "*albumen.*"

It has, however, hitherto remained an unnoticed fact that all seeds which have *two* so-called seed-coats, are all alike *destitute of an "albumen;"* and that all seeds *provided* with an albumen, have only one *solitary seed-coat, aside from the albumen itself.**

In many other seeds, as in those of the Osage orange (Maclura) and several Cactaceæ, &c., the albumen is thinned out, in some places, into a so-called "endopleura" or interior seed-coat, while in other parts of the seed the sheet of this self-same "internal seed-coat" thickens up into a bulky albumen, conformably to the configuration of the germ it encloses and of the *testa* which contains both.

An inspection of the *immature seed* of all the so-called *ex*-albuminous forms, *i.e.*, those which, like the pea-nut, peach, and almond, are destitute of an albumen, discloses the fact, that in this juvenile

* The testa, or exterior seed-coat, frequently exhibits a diversified structure of external and internal surfaces. In the seed of the magnolia, that of the grape, &c., the exterior surface of the otherwise bony seed-coat, which encloses the albumen, is fleshy; as is the entire testa of the blue cobosh (Caulophyllum).

condition, all these seeds have, like all the rest (viz., the "albuminous seeds") a large *succulent albumen-zone*, wherein the germ ("embryo sac," &c.) is developed, at the expense of the former. During the process of ripening, in all the *nutty*, or "*ex*-albuminous" seeds, the primitive albumen becomes gradually *exhausted*, leaving its entire cell-tissue compressed and empty behind, as the delicate endopleura or internal seed-coat. In all the other seeds, on the contrary, this succulent albumen-zone remains the storehouse for the germinating seed to draw its substance from. In the honey-locust and the allied coffee-nut tree (Gymnocladus) in germination, the flinty albumen dissolves into a sort of gum, like gum-arabic.

In point of fact, the "endopleura" and the "albumen" are one *identical organ*.

This evident identity of the original albumen and subsequent second seed-coat, settles at once the old and perplexed question about the erroneously supposed "*gymnospermism*," whether of Labiatæ, or of Coniferæ and their allies, the Taxineæ, Gnetaceæ, Casuarinæ, and Cycadeæ.

Since we now know, what *parts* all seeds *consist of*, these tribes are by no means to be considered as "abnormally" or even "monstrously" organized (as a prevalent theory still holds), but that, *e.g.*, all the *edible pine-nuts* are *true utricular capsules*, and contain, each, a *complete seed;* which (like the mature cocoa-nut kernel) loosely adheres to its one-seeded pistil, as is the case, *e.g.*, with all grasses, grains, and the knot-weeds; their true ovules being mostly sessile (as in the entire orders of Polygonaceæ and Nyctaginaceæ, with only few exceptions) and considerably coherent with the true pistil (or stigmatiferous "utricle"). In the above-mentioned coniferous tribes, these one-seeded pistils are provided with a pervious, "open" stigma; a case correspondingly represented in the duck-weeds (Lemnaceæ), which, however, have their seeds borne upon a *funiculus*, — leaving no space for a doubt.

The seed itself, of Coniferæ, is a complete one, consisting (1) of a germ; (2) an (oily) albumen; and (3) one thin, brown, membranaceous seed-coat (the *testa*), readily separating from the utricle or nut-shell which surrounds it, as in the well-known cases of the pine-nuts of California, Italy, and that of Switzerland (*Pinus lembra*).

Thus, it is clear that the pine-*scales* are only a woody cup or *cob*, of indurated "saucers" or involucres (as with acorns) that arise in the axils of delicate and sometimes colored bracts. Similar involu-

cral cups we find in the harsh cones of the alder, and in the sterile aments of the wild-hemp tribe.

The wing-like appendages of the pine-nuts represent so many *paleæ* or *floral chaff* (like that of grains and bulrushes, &c.).

In the remarkable case of Welwitschia, the "kettle-drum pine" of western tropical Africa, no such indurated scales, but only the purpureous bracts, as are those of flowering larch-trees, are developed. The true *perianth* — as acknowledged on Dr. Hooker's plate, viii. — is here a delicate, foliaceous, two-winged one, epigynously concrete with the nut, as is the chaff of pines and two-seeded capsules of Araucariæ. Nevertheless, the same identical organ is erroneously styled "a pericarp" on the preceding plates, by a *lapsus calami* of the same author, on the uncritical bias of *so-called* "gymnospermism." * The so-called gymnosperms all have *closed pistils!* — with an open stigma.

It is thus clear, that there is *no "break"* in the vegetable kingdom: all forms uniting into a complete, connected, and harmonious system of mutual typical affinities or correlations, to be discussed in detail in a subsequent paper.

* The untenable theory, here referred to, considers the pine-*scale* as a "pistil;" destitute, however, of any of the *distinctive attributes* of a pistil; being without a suture, without a stigma, and without any fructification through its instrumentality.

The true (one-seeded, *pluri-ovulate*) pistil, or "utricle" was wrongly regarded as an (abnormally "*naked*") "ovule;" with an *abnormally rostrate* "exostome," viz., the (open) stigma! Next followed (after this *pseudo* "testa") the true seed-coat under the denomination of an "endopleura,"— and an "*albumen*" *besides*, containing the embryo.

The true solitary seed-coat adhering to the pistil, the shrunken albumen will often be found lying loose inside.

The contended fruit of the well-known yew-tree contains (1) an embryo, imbedded within (2) an albumen, which is surrounded (3) by a tawny seed-coat. The latter loosely adheres (4) to a thickish *capsule*, which is itself (5) *covered by a thick calycine layer!* — in the exact likeness of an acorn, a hazelnut, or the nut of the sweet gale (Myrica; the wax-myrtle or bayberry), which indeed seems to reproduce the true (*epigynous*) structure of the former on a reduced scale. Among Compositæ, *Polymnia Uvedalia*, the "nutted leaf-cup," likewise connects with Cupuliferæ, through Ambrosiaceæ and Cannabinæ.

The cup of the yew-tree thus remains to be properly interpreted as a fleshy cup wrapt in dry scales, like those of the acorn and wax-myrtle on the one, and the succulent [illegible] involucres on the other hand, combined into one.

4. The Monocotyledon, the Universal Type of Seeds. By Thomas Meehan, of Germantown, Pennsylvania.

It must be evident to the readers of my paper at the Chicago Meeting of the Association on "*Adnation in Coniferæ*," that the observations there detailed could scarcely be accounted for if the belief be true, which is generally held by Botanists, that *the leaf originates at the node from which it seems to spring.* It is not, however, an object with me to attack existing theories or establish new ones; but simply to present facts as I see them. If I suggest a meaning to the facts, it is to excite thought in others, as facts are of no value, unless some one makes use of them. The origin of the leaf will, no doubt, prove a question which will in time take care of itself. But this generalization cannot be avoided by the readers of that paper, that the whole plant is originally an unity, and that the subsequent formation of elementary organs, and their complete development, or absorption into one another, is the result of varying phases of nutrition. The leaves in *Coniferæ* were found to be free or united with the stem, in proportion to the vigor of the central axis.

Following up this subject, I now offer some facts which will show that all seeds are primarily monocotyledonous; and that division is a subsequent act, depending on circumstances which do not exist at the first commencement of the seed growth.

It is well known that in some species of coniferous plants the number of cotyledons varies. I have noticed in addition to this, that whether the cotyledons are few or many, *there is no increase in the whole cotyledonous mass.* In the Norway spruce, *Abies excelsa*, there are sometimes as many as ten cotyledons, at others only two. In the latter case they are broad and ovate, while in the former they are narrow and hair-like. In short, when in the two-leaved state it is not possible to note any difference between a seedling Norway spruce and a Chinese arbor vitæ, *Biota orientalis*, except by the lighter shade of green. The two-leaved condition is not common, but specimens of threes and others I exhibited to Drs. Torrey and Gray at the Troy meeting. Any one who will examine sprouting seeds of the Norway spruce will agree to the proposition that *the cotyledons are not original and separate creations; but a divided unity.*

My next observations were on some acorns of *Quercus agrifolia*, The division into cotyledons was numerous and irregular. Cut across vertically, some represented the letter C (with the left side doubled), others the letter N (inscribed in a circle), and again with four cotyledons the letter M. Here again it was clear that, however the form and number of the cotyledons, *there was no increase of the original cotyledon mass.*

Examining sprouting peach kernels, the variations in form and number were of the most remarkable character. I need not repeat them in detail here, as they are reported in the April and May *Proceedings of the Academy of Natural Sciences of Philadelphia.* In addition to the fact of no increase in the whole cotyledon mass, it was here clear that when *the cotyledons were duplicated, the duplications at least were subsequent to the original ones.*

Still so far nothing had been seen to indicate when the first pair of cotyledons were formed. *Quercus macrocarpa* and *Quercus palustris* were silent to my questions. Of a large number, I found no variation whatever. Each mass was divided smoothly and exactly into two cotyledons.

Quercus robur, the English oak, however, gave some curious evidence. Two germs were numerous under one seed coat, and often three, and the cotyledons took on a variety of forms. But there was never any more increase in the cotyledonous mass than if but two lobes had been formed, and there was no more rule in the division than there would be in the sudden breakage of a piece of glass. A detailed account of these will also be found in the *May Proceedings of the Academy of Natural Sciences of Philadelphia.*

Quercus rubra, the American red oak, furnished the one link wanting to connect the first division into lobes with the other phenomena. *All* the acorns examined had three or four sutures on the cotyledon mass, and extending all along the longitudinal surface externally, without any reference to cotyledonal divisions. These sutures extended sometimes but a line in depth, at others almost to the centre of the mass, — always accompanied by the inner membrane, as is the case in ruminated seeds. The whole mass was divided only in two parts in any that I examined of this species, but the division was always in *the direction of the sutures.* Hence each cotyledon was very irregular. Sometimes one-third the mass only went to one, while the other had two-thirds of the whole mass. It *was easier to burst in the weakest line of resist-*

ance. But the interest for us is to note that originally the cotyledonous mass was an unit, — then the sutures or fissures were formed; and ultimately the two divisions of the lobes followed in their direction. *The division was the last condition, — not the first.*

I know how much we should guard against generalizing on a limited supply of facts; but it requires an effort to believe that oaks, pines, and peaches, as we have seen primordially monocotyledonous, are in this respect different from other so-called dicotyledonous plants.

And if we grant that all seeds are primarily monocotyledonous, may we not ask *why in any case are they divided?* We have seen that there is no increase of mass in the division: the same amount is furnished in one as in many. Would it in any way injure the Indian-corn to have its mass divided into two lobes? or would not the plantlet be as well provided for if the acorn were in one solid mass? Division would seem to be a necessity occurring subsequently to organization, and existing from the position of the plumule alone. In monocotyledons, as we know them, the plumule is directed parallel to, or away from, the cotyledonous mass, when, of course, on this theory it remains an undivided mass. But in the dicotyledonous section, the plumule is directed towards the apex of the mass; and, as we know in the case of roots against stone walls, or mushrooms under paving stones, the disposition in the growing force of plants is to go right forward, turning neither to the right nor to the left, so in this mass of matter the development of the germ would make easy work of the division, and no doubt often at so early a stage, as to give the impression we have hitherto been under, that the division is a primary and essential process.

6. On the Seemingly One-ranked Leaves of Baptisia Perfoliata. By H. W. Ravenel, of Aiken, S. C.; with remarks by Asa Gray, of Cambridge, Mass.

Aiken, S. C., May 17, 1871.

Professor Asa Gray.

My dear Sir, — I have been lately making some observations on the leaf arrangement of *Baptisia perfoliata*, to which I wish to call your attention. In a foot-note to your "Introduction to Structural and Systematic Botany," p. 134, you state: "In the course of the summer, the leaves of Baptisia perfoliata, which are really five-ranked, often appear to be monostichous or one-ranked; but this is owing to a torsion of the axis."

From an examination of a number of living plants in the woods, I feel satisfied that the leaves are distichously alternate (phyllotaxis ½), and that the twisting of the axis is alternately from right to left and from left to right, the torsion taking place whilst the leaves are unfolding; and that this torsion is owing to the shape of the leaf and its oblique adnation to the stem.

The reasons for this opinion I will now proceed to state. This species, like other Baptisias, has spreading branches. The branches are not much subdivided, but frequently continue straight for several nodes. They point indiscriminately to any or all points of the compass, but the leaves are all arranged (when there are several continuous internodes) in one rank apparently; sometimes presenting one face, sometimes the other, to the sun. The leaves are obliquely adnated to the stem, but adjust themselves to the angular divergence of the branches, so as to preserve a general vertical position with the earth. A full-grown leaf presents an oval outline, concavo-convex, obliquely funnel formed, the portion below the stem being about one-quarter the length of the blade; the back (or normally under side) convex, the front (or upper side) concave.

The alternate torsion of each internode in opposite directions can be traced by the lines of coloring in the stem, but is more clearly seen by stripping a portion of the bark downward from one leaf to the other, when it is seen to wind spirally through half the diameter of the stem, from right to left and from left to right,

alternately through the extent of the branch, the torsion being pretty uniform through the entire internodal spaces. When a branch is developed, the torsion of the first internode is very slight, as there is less angular divergence to be overcome in order to adjust its leaf to a vertical position, but complete torsion takes place in the next internode, and so continues alternately to the extremity.

At the ends of the growing shoots, the young leaves are arranged alternately in præfoliation, each embryonic leaf folded longitudinally, so that the opposite edges are brought together (conduplicate).

As I stood over these plants in the woods, pencil in hand, taking the above notes, I could see the process of torsion almost going on before me in its various stages. As soon as the young leaf is sufficiently developed to unfold, there is a gradual twisting of the soft succulent stem, so as to adjust the leaf to its vertical position. If the previous spiral was from right to left, the next is in the opposite direction, as if to untwist the stem and restore the axis to a right line.

Now, two interesting questions are suggested; viz., —

1st. What is the cause of this alternate torsion; and

2d. Whence the necessity of this peculiarity, for the well-being of the plant.

The leaves of this species are remarkably strong, thick, and leathery, with the ribs and frame-work ramifying and anastomosing in all possible directions. The marginal outline, being somewhat contracted, produces a funnel-shape, and its oblique adnation to the stem gives it a firm grasp. When therefore the young leaf is about to unfold itself, the torsion of the stem is caused by the effort of the leaf, clasping the stem obliquely, to adjust itself in relation to the light, and assume a vertical position, — the alternate twisting from one side to the other being the most natural mode, or rather one that relieves the stem of a continual torsion through its entire axis. The equilibrium is thus restored, each alternate leaf standing in its proper natural position.

Why it is necessary for the well-being of the plant that the leaves should assume this vertical position will probably be found in a microscopical examination of the two surfaces, which for want of a good instrument I am unable to verify. It will probably be found like the compass-plant, Silphium lacciniatum, to have the stomata equally distributed over the two surfaces. Indeed from

examination with the naked eye, and by the aid of an ordinary pocket lens, I would infer this to be the fact.

Mr. Ravenel's observations and his conjecture are both correct. As to the note in my Structural Botany, I must have taken it for granted, without proper examination, that the phyllotaxis of *Baptisia* was of the $\frac{2}{5}$ order, because it is so in most or many common Leguminosæ. I find however that in *B. australis*, *leucantha*, and *alba*, and even in *B. perfoliata*, — being all the species here in cultivation, the phyllotaxis at the base of the main stem is of the $\frac{1}{3}$ order, *i.e.*, the fourth leaf vertically over the first, unless altered by a twist of the axis; but that after the first or sometimes the second cycle, and especially on the branches, the leaves are two-ranked. In this respect *B. perfoliata* and its congeners agree. But in *B. perfoliata* only do we observe the curious torsion of each internode, alternately right and left, as shown by Mr. Ravenel, which brings the leaves of the branch apparently into a single rank. The branches being horizontally reclined, the leaves become really vertical and expose the two surfaces about equally to the light. And on microscopical examination of the epidermis, I find, as is common in analogous cases, and as Mr. Ravenel suspected, that the stomata are about equally numerous on either face. Whether the leaves assume the vertical position because the stomata occupy both surfaces, or whether the stomata are so distributed because the leaves stand edgewise to the zenith, is a question. The simple fact is, that the two things are thus correlated, and that this correlation is ordinarily essential to the well-being of the plant. But I may remark that the stomata do not manifestly make their appearance until the leaf is pretty well developed. And that the present species is peculiar in this distribution of the stomata. The leaves of the other species which I have examined, such as *B. leucantha*, which retain their horizontal position, bear stomata only on the lower surface, none at all on the upper.

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6. On the Relation of the Tendril to the Phyllotaxis in certain Cucurbitaceous Plants. By H. W. Ravenel, of Aiken, S.C.

I propose in the following paper to give a record of observations made on the leaf arrangement and tendrils of certain Cucurbi-

taceous plants, examined this season; — not so much as presenting any thing decisive on a difficult subject which has attracted much attention from botanists, but simply as a record of facts, which, with other recorded observations, may tend to elucidate the matter.

Of the forty-two individual plants examined, comprised in seven species and varieties of cucurbits, I have found some characters constant throughout, whilst others are irregular and governed by no apparent law.

The leaf arrangement is constantly and uniformly 5-ranked, *i.e.*, there are five leaves to complete the cycle, so that the sixth leaf stands directly over the first, the seventh over the second, &c., and the ascending spiral of leaves forms two revolutions round the stem to complete a cycle; that is, the leaves are distributed at regular intervals of two-fifths angular divergence around the stem. I find, however, great *irregularity in the direction of the ascending spiral of leaves*, varying in individuals of the same kind, — some with spirals ascending from right to left, and others taking the opposite course. Whatever direction the spiral takes upon any axis, either of the leading shoots or of laterals, is continued constantly throughout its length; and when lateral branches arise, these sometimes continue the direction of the previous spiral, but often change to the opposite course.

The tendrils are uniformly lateral, on the same node and plane with the leaves, and at a distance corresponding to one-fifth of the circumference of the stem; or, in other words, each tendril occupies a point midway between its own nodal leaf, and the next leaf above.

The tendril is also constantly on that side of its leaf which points in the direction the ascending spiral takes; *e.g.*, if the spiral is from left to right, the tendril stands on right of leaf, and *vice versâ*. This character is constant. The tendrils vary, therefore, with the leaf arrangement, and always indicate the direction of the spirals.

RECORD OF OBSERVATIONS MADE IN EARLY PART OF JUNE.

Cucumber (Cucumis sativus). Phyllotaxis $\frac{2}{5}$.

2 vines examined — Leading shoots with spirals from Right to Left.
4 „ „ „ Left to Right.

In the lateral branches examined, all took direction opposite to leading shoots.

Gherkin (Cucumis sativus var.) Phyllotaxis $\frac{2}{5}$.

1 vine — Leading shoot with spirals from Left to Right.

In the laterals there was irregularity; some taking one direction, and some another.

Early Bush Squash (Cucurbita melo-pepo). Phyllotaxis $\frac{2}{5}$.

8 vines — Leading shoots with spirals from Right to Left.
3 „ „ „ Left to Right.

The few lateral branches have spirals in direction opposite to those of leading shoots.

Yokohama Squash. Phyllotaxis $\frac{2}{5}$.

2 vines — Leading shoots with spirals from Left to Right.
2 „ „ „ „ Right to Left.

Gourd (Lagenaria vulgaris). Phyllotaxis $\frac{2}{5}$.

3 vines — Leading shoots with spirals from Left to Right.

Watermelon (Cucumis citrullus). Phyllotaxis $\frac{2}{5}$.

9 vines, — Leading shoots with spirals from Right to Left.
5 „ „ „ „ Left to Right.

Mango (Sechium edule). Phyllotaxis $\frac{2}{5}$.

3 vines, — Leading shoots with spirals from Left to Right.
Laterals with spirals in opposite direction.

Later in the season I made the following record:

July 3, — *Watermelon* (A).

One leading shoot with spirals from Right to Left.

1, 2	laterals had spirals R. to L.	10	lateral had spirals L. to R.
3	„ „ L. to R.	11	„ „ R. to L.
4, 5, 6	„ „ R. to L.	12, 13	„ „ L. to R.
7, 8, 9	„ „ L. to R.	(Then follow 4 nodes branchless).	
(Then follow 3 nodes branchless).		14	lateral had spirals L. to R.

July 4, — *Watermelon* (A).

Another leading shoot with spirals from Right to Left.

1, 2	laterals with spirals L. to R.	9	lateral with spirals L. to R. (2 nodes branchless.)
3, 4	„ „ R. to L. (then follow 3 nodes branchless.)	10	lateral with spirals L. to R. (2 nodes branchless.)
5	lateral with spirals R. to L. (2 nodes branchless.)	11	lateral with spirals L. to R. (3 nodes branchless.)
6	lateral with spirals L. to R. (1 node branchless.)	A young fruit in axil of	
7, 8	laterals with spirals L. to R. (2 nodes branchless.)	12	lateral with spirals L. to R. (No more branches to end of shoot.)

July 4, — *Watermelon* (B).

Leading shoot with spirals from Right to Left.

1, 2	laterals with spirals R. to L. (1 node branchless).	18	lateral with spirals L. to R.
3, 4	laterals with spirals L. to R.	19	„ „ R. to L.
5	„ „ R. to L.	20	„ „ L. to R.
6, 7, 8	„ „ L. to R.	21	„ „ R. to L.
9, 10	„ „ R. to L.	22, 23, 24, 25	„ „ L. to R.
11, 12,	„ „ L. to R. (2 nodes branchless.)	26, 27	„ „ L. to R. A young fruit in axil of
13	lateral with spirals L. to R.	28	lateral with spirals L. to R.
14	„ „ R. to L.	29	„ „ R. to L.
15, 16	„ „ L. to R.	30, 31, 32	„ „ L. to R. (1 node branchless.)
17	„ „ R. to L. (1 node branchless.)	33	lateral with spirals L. to R. No more branches to end of shoot.

July 5, — *Gourd* (A).

Leading shoot with spirals from Left to Right.

1, 2	laterals with spirals R. to L. (2 nodes branchless.)	6	lateral with spirals R. to L. (1 node branchless.)
3, 4	laterals with spirals R. to L. (5 nodes branchless.)	7, 8, 9, 10	laterals with spirals R. to L.
5	lateral with spirals R. to L. (1 node branchless.)	11, 12, 13	„ „ R. to L. No more branches to end of shoot.

July 5, — *Gourd* (B).

Leading shoot with spirals from Left to Right.

1	lateral with spirals R. to L. (5 nodes branchless.)	10, 11	laterals with spirals R. to L. No more branches to end of shoot.
2, 3	laterals with spirals R. to L. (1 node branchless.)		

July 5, — *Sechium edule.*

One leading shoot with spirals from Right to Left.

1	lateral with spirals L. to R. (1 node branchless.)	4, 5, 6, 7	laterals with spirals L. to R.
2	lateral with spirals L. to R. (1 node branchless.)	8, 9, 10	„ „ L. to R. No more branches to end of shoot.
3	lateral with spirals L. to R. (1 node branchless.)		

Another leading shoot on same vine Left to Right.

First four nodes branchless.		2, 3, 4, 5	laterals with spirals R. to L.
1	lateral with spirals R. to L. (1 node branchless.)		No more branches to end of shoot.

July 5, — *Gherkin*.

One leading shoot with spirals from Left to Right.

1	lateral with spirals from R. to L.	5, 6	laterals with spirals R. to L.
	1 secondary lateral on above R. to L.	7	„ „ L. to R.
2	lateral with spirals from R. to L.	8	„ „ R. to L.
3	„ „ „ L. to R.	9	„ „ L. to R.
	1 secondary lateral on above R. to L.	10, 11,	„ „ R. to L.
	2, 3, 4, 5, 6, 7 „ „ L. to R.	12, 13, 14, 15	„ „ L. to R.
4	lateral with spirals from L. to R.	No more branches to end of shoot.	

An analysis of the above record shows that the leaf arrangement of all the specimens examined was on the $\frac{2}{5}$ plan; that vines of the same kind had sometimes the spiral ascending from right to left, and sometimes the reverse, but in whatever direction it commenced, it so continued to the end of the shoot; that the primary laterals sometimes changed the direction of the spiral from that of the leading shoot, and at other times continued it; that the secondary laterals exhibited the same irregularity; that the tendril was uniformly at that side of its leaf which indicated the direction of the ascending spiral, and at a distance of one-fifth angular divergence, or at a point midway between its leaf and the next leaf above in the ascending spiral.

IV. ETHNOLOGY.

1. On a Form of the Boomerang in use among the Mogui-Pueblo Indians of North America. By C. C. Parry of Washington, D. C.

The Boomerang as a hand projectile in common use among the natives of Australia, for hunting wild animals, and as a weapon of defence, has been generally regarded as peculiar to that remote district.

The complicated mathematical principles involved in the movements of this projectile have been made subjects of special investi-

gation, including a paper presented several years ago before this Association, by its present permanent Secretary, Professor Joseph Lovering.

The object of this communication is to call attention to the fact that a similar weapon, less perfect in its complicated mechanical movements, and applied to similar uses, has been brought to light among the Mogui-Pueblo Indians of Central Arizona.

By the kindness of Professor Henry, of the Smithsonian Institution, I have obtained the privilege of making known the facts on this subject, and exhibiting before the Association one of the two specimens now deposited in the museum of that institution.

This singular tribe of semi-civilized Indians, devoted to agriculture and a rude style of mechanic arts, has been visited at different times by various explorers; the first authentic accounts being derived from the celebrated expedition of Coronado in 1540. Owing to their peculiar location, encompassed by deserts, and thus in great measure cut off from intercourse with other tribes, they have maintained their singular habits and modes of life almost unchanged during the historic period. In fact the accounts given of this tribe by the historian of Coronado's expedition, over three hundred years ago, would apply almost *verbatim* to the *Moguis* of to-day.

In none of the published accounts of this tribe that have come under my notice has any mention been made of the use of any peculiar weapon corresponding to the Australian boomerang.

In 1869, Dr. Edward Palmer, then in the employ of the Smithsonian Institution as a collector of ethnological specimens in connection with our native Indian tribes, accompanied by a small military escort from Fort Defiance, visited the Mogui villages. Intent on noting and collecting every thing relating to the modes of life and habits of this singular people, his attention was attracted one evening, during their stay, by an order given out according to the custom of the tribe, from the top of one of their loftiest dwellings, designating a certain number of hunters to assemble at early dawn the next day for a concerted rabbit hunt. It seems that these animals (whose movements somewhat resemble that of the Australian kangaroo in their sudden leaps and dodging motions) not only constitute an important article of diet to the inhabitants of that district, but also on account of their prolific nature, and destructive habits in connection with ordinary crops, require to be kept within reasonable limits. Hence occasional concerted hunts

are undertaken for the double object of procuring animal food, and protecting growing crops. In accordance with this appointment, the hunting party assembled at daylight, all being more or less supplied with weapons of the following description (*specimen exhibited*). It is a stick of hard wood flattened on both sides to a thickness of one-half inch, having an average width of two inches, and curved near the middle at an obtuse angle of 130°, furnished at one end with a handle. This was thrown by a direct whirling motion, aimed at the legs of the leaping rabbits, and generally, whenever the object was fairly presented, proving successful in bringing down the game by fracturing their legs.

The obvious difference between this and the corresponding Australian weapon consists in the fact that the latter, by a variation of curves on one of its faces, gives rise to those complicated movements, by which an object is hit by aiming at a nearly opposite direction; thus, taking an animal by surprise, and not affording an opportunity for dodging. This marked difference at once suggests the inquiry, whether the Mogui boomerang may not represent one of the early stages in the development of the more complete weapon, which, by a larger and longer experience among the Australian natives, has been brought to a perfection not yet attained by the limited tribe of Mogui Indians.

Accident, and perhaps necessity, may have first determined the use of a crooked instead of a straight stick as a direct projectile; experience would eventually fix upon a more definite shape, and a certain angle most suitable for the purposes desired; furthermore, a rudely formed weapon, which, from the nature of the material used and rough workmanship, would almost necessarily give rise to a variety of curves, would, as a result of experience, develop the curves best adapted to particular movements, and eventually become fixed in the most appropriate shape for executing the complicated movements desired.

It may also be noted in this connection, that the material of which the Mogui boomerangs are made does not grow in the section of country they inhabit, but has to be procured by trade with the more roving Nevajo Indians. Hence Dr. Palmer found some difficulty in procuring his specimens of this article by purchase, on account of the value placed on them by their possessors.

In early historic times, when theorizing was in vogue to account for the supposed Eastern origin of the North-American Indian tribes, the existence of the boomerang would have been seized on

at once as an indisputable proof of the original derivation of the Mogui-Pueblo Indians from Australia!

Fortunately, this discovery of Dr. Palmer has fallen upon times when less weight is given to isolated facts, and we are content to note the singular coincidence by which a peculiar style of weapon has originated independently, to meet analogous natural wants, at points of the earth's surface almost antipodal! So far the civilized uses of this ethnological curiosity have been confined to abstruse mathematical calculations of its complicated movements, while it furnishes a dangerous plaything for mischievous school-boys.

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2. The Great Mound on the Etowah River, Georgia. By Charles Whittlesey, of Cleveland, Ohio.

Not having seen a detailed description of this mound, I made a visit to it in behalf of the Western Reserve Historical Society, in April, 1871, on the suggestion of a distinguished officer of our Army. It stands upon the north bank of the Etowah, about two miles below where it is crossed by the Chattanooga and Atlanta Railway, near Cartersville. Its form, size, and elevation are singular and imposing. It occupies the easterly point or angle of a large and luxuriant river bottom, a part of which is subject to inundations. The soil is a deep, rich, black loam, covering several hundred acres, which has been cultivated in corn and cotton, since the Cherokees left it about forty years since.

I was compelled, by bad weather, to make the survey in haste. The bearings were taken with a prismatic compass, the distances were measured by pacing, and the elevations obtained with a pocket level. They are therefore subject to the corrections of future surveyors. Its base covers a space of about three acres, and stands at a level of twenty-three feet above low water in the river. In great floods the water approaches near the mound on the west, but has not been known to reach it. The body of the mound has an irregular figure, as the plan here presented shows. It is longest on the meridian, its diameter in that direction being about 270

feet. On the top is a nearly level area of about an acre, the average height of which is 50 feet above the base. A broad ramp winds upwards from the plain, around the south face of the mound, to the area on the top.

Like some of the pyramids of Egypt, it has two smaller ones as tenders: one on the south, *C;* another on the south-east, *B;* each about 100 feet distant, their bases nearly square, and of nearly equal dimensions. If they were not in the shadow of the great mound they would attract attention, for their size and regularity. The ground at *B* is three feet higher than at *C.* All of them are truncated. The mound *C* is not a perfectly regular figure, but approaches a square, with one side broken into three lines. Its height above base is 18 feet. The bearing of its western side is north 10° west, and the length on this side on the ground 47 paces, having been somewhat spread out by ploughing around the foot. On the east is a ramp with a slope of one to two degrees which allows of ready ascent by persons on foot.

The slopes of all the mounds are very steep and quite perfect; in some places still standing at an angle of 45°. *B* is a regular truncated pyramid, with a square base; about 106 feet on a side, the faces bearing 5° west of the meridian. Its elevation is 22 feet. There is no ramp or place of ascent which is less steep than the general slopes.

Towards the south-east corner of the surface of *B*, is a sunken place as though a vault had fallen in.

The proprietor has managed to cultivate the summits of all the mounds, regarding the group in the light of a continual injury by the loss of several acres of ground. Most of the material of the mound is the rich black mould of the bottom land, with occasional lumps of red clay. The soil on their sides and summits produces corn, cotton, grass, vines, and bushes in full luxuriance. The perimeter of the base of the great mound is 534 paces. As the ground had been recently ploughed and was soaked with a deluge of rain, a pace will represent little more than two feet. I give the circumference provisionally at 370 yards. The area on the top is like the base, oblong, north and south; but its figure is more regular. Its perimeter is 231 paces.

From the centre of the pyramid *C*, a line on the magnetic meridian passes a few feet to the west of the centre of the platform, on the summit of *A.* Its sides are nowhere washed or gullied by rains. Prior to the clearing of the land, large trees

flourished on the top and on the slopes. I estimate its mass to contain 117,000 cubic yards, which is about four-fifths of the British earth monument on the field of Waterloo.

At the base the ramp is fifty feet broad, growing narrower as you ascend. It curves to the right, and reaches the area on the top near its south-west corner. Twenty-five years since, before it was injured by cultivation, visitors could easily ride to the summit on horseback, along the ramp. From this spot the view of the rich valley of the Etowah, towards the west, and of the picturesque hills which border it on either side, is one of surpassing beauty.

About 300 yards to the north rises the second terrace, or bottom of the valley, composed of red clay and gravel. Near the foot of it are the remains of a ditch, enclosing this group of mounds in an arc of a circle, at a distance of about 200 yards. The western end rests on the river below the mounds, into which the high waters back up a considerable distance.

It has been principally filled up by cultivation. The owner of the premises says there was originally an embankment along the edge of the ditch on the side of the pyramids, but other old settlers say there was none. If the last statement is correct, a part of the earth composing the mounds can be accounted for.

Its length is about one-fourth of a mile, and it does not extend to the river above the mounds. Near the upper end are two oblong irregular pits, twelve to fifteen feet deep, from which a part of the earth of the mounds may have been taken. Their largest diameter varies from 150 to 200 feet, and the breadth from 60 to 70. The ditch is reputed to have been thirty feet wide, and ten feet deep. Two hundred yards to the north-east of *A*, are the remains of two low mounds within the ditch, and near the large pits. Five hundred yards to the north-west, on the edge of the second terrace, is a mound which is yet eight feet high, although it has been industriously ploughed over more than thirty years. On the opposite side of the river one-fourth of a mile below, and on the same side two miles below, are said to be small mounds.

On the summit of a rocky hill, two and a half miles north-west, which overlooks the valley of the Etowah towards Rome, and also the hill country on the south, is an enclosure of loose unhewn stones, known as the "Indian Fort." It has now the appearance of a heavy stone fence which has fallen down. There are six openings or entrances, having a breadth of ten to sixty feet, situated at irregular distances. It is an irregular oval figure enclosing the

rocky summit of the hill, the largest diameter of which is 220 paces, and the shorter 200. The elevation of the knob, at the centre, is fifty feet above the terrace or bench, on which the lines of loose stone are lying. This interior space is principally cleared of loose stone, and shows bare ledges of lime rock, in horizontal layers.

The hill is covered with an open growth of oaks. There is nothing in this structure suggestive of a *Fort*, except its elevated position, which, however, is by no means inaccessible. The openings are too wide, and too numerous, to warrant the idea of a defensive work. It is more probable that it was the scene of imposing public processions and displays, and was approached by crowds of persons from all sides through the openings. The rude wall or line of stones would be the necessary result of clearing the ground of the blocks of limestone once scattered profusely over the surface.

Near where the railway from Cartersville to Cedarville crosses Pettit's Creek, at the base of the limestone bluff, about half a mile east of the "Fort," is an artificial pile of small stones, which was once about eighteen feet in height. It is now very much injured by persons in search of treasure and of relics, who have formed a crater at the centre nearly down to the ground, throwing the stones over the sides. It must have been a regular cone, with smaller heaps attached around its base, which was irregular, and about 160 feet in circumference. This mound of stones does not differ from those raised by the red men over the remains of their dead chiefs.

A few days before I was at the great mound *A*, a rude stone effigy of a female was ploughed out near its base on the north side. It is quite grotesque, resembling the uncouth carvings in wood of the Indians of the north. Its height is fourteen inches, its weight thirty-six pounds; and the material is the limestone of the region.

I have a photograph of it, viewed on three sides, and expected to have had a copy in plaster, for exhibition here, but it has not been received. On the hips and back are colored zigzag lines of white and brown, intended for ornament. Some years since a male, probably the mate to it, was ploughed out near the same place; also an earthen vase and other pottery, with flint discs. The first found image was lost or destroyed, and the other soon will be. In style and artistic execution, they clearly appear to be the work of the present red man, and exhibit no relation to the mound-builders.

Mr. Tumlin, the owner of the premises, and Mr. Sage of Cartersville, who knew the country while the Cherokees were in possession of it, state that the summit of the great pyramid was a fortified village, surrounded by pickets of wood and a slight embankment. This parapet is still visible, but is, at least in part, owing to the furrows turned outward in ploughing, and, until recently, the stumps of the pickets were struck by the plough. Near the south-east corner of the area, on the top, is a low mound. It is a third of a mile, at the nearest point, to where there is land of a height equal to the mound, and therefore it was a place easily defended. Although the Cherokees made use of it as a fort against the Creeks, they always denied having any knowledge of the race or the persons by whom the mound was erected. The gentlemen above named questioned them repeatedly on this point, and always received the same answer. If it had been designed as a place of defence originally, a much less broad and gentle road to the summit would have been made.

I was attracted to this mound and its surroundings as a type of the flat-top pyramids, so common on the waters of the Gulf of Mexico, which have been by some archæologists attributed to the present race of red men. In Florida and in Alabama, the early English and Spanish travellers found Indian Caciques with their wigwams on the top of such mounds, around which were the villages of their tribe. Instances are given where Indian towns occupied spaces surrounded by ancient embankments of earth, both with and without mounds. But I know of no instance in history or books of travel,—whether Spanish, French, or English,—where Indians were observed erecting mounds, embankments, or forts of earth, like those of the mound-builders.

Mr. F. F. Haven, long distinguished in archæology, as the Secretary of the American Antiquarian Society at Worcester, Mass., in his article in the Smithsonian Contributions for 1855, has referred to a supposed instance of an intrenched fort made by the Aurickarees, in a bend of the Missouri River, above Council Bluffs. The description of this fort, by Lewis and Clark, does not give it the character of an earthwork with ditches for defence. It was a temporary breastwork of logs and earth and stone, hastily thrown up, such as are common in Indian warfare, and in all warfare.

The Indian forts, which were attacked by Champlain, in north eastern New York, in 1609, were constructed of pickets set in the ground, strengthened by interlacing branches and poles, secured by

bark and withes. During the French wars with the Iroquois, on the waters of Lake Ontario, they met with nothing more advanced than these light stockades. The pickets were set in the earth, and a low bank raised against them from both sides, to give them a more firm support. In no case was the bank or ditch relied upon as a protection of those within, or as an obstacle to those without. They were of a profile too slight for this purpose.

The north-western Indians have been questioned in numerous instances as to the authors of the earthworks of the West. They universally deny having any knowledge or tradition of the persons who built them; a tradition which could not have been lost, or the art of making them. The relics which are found in the mounds, in connection with the first or oldest burials, although there are resemblances, differ from the relics of the red men in almost all particulars. If stone axes or mauls of the Indian type have been found in the mounds, they are very rare, and of doubtful authenticity. The modes of burial by the mound-builders, and by the recent red man, are wholly different. The last-named race were not miners of copper or copper-workers. In the implements of the two races there are resemblances, especially in those which are made of flint, but no greater than in those of the ancient races in Europe, where no connection is claimed.

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3. Ancient Rock Inscriptions in Ohio. By Charles Whittlesey, of Cleveland, Ohio.

(Abstract.)

Several diagrams were presented to the section representing rock sculptures in Ohio, that are presumed to be ancient and to have some significance. The largest is a tracing made by Dr. J. H. Salisbury, of Cleveland, with the assistance of Mrs. Salisbury, from a mural face of conglomerate, near the famous "Black Hand" in Licking County, O. Once there was a space of ten or twelve feet in height, by fifty or sixty feet in length, covered by these inscriptions. Most of them have been obliterated by the recent white settlers.

In 1861, Dr. Salisbury took copies from a space about eight by fifteen feet, by laying a piece of coarse muslin over them, and tracing such as remain uninjured, life-size, on the cloth. In this space there are found to be twenty-three characters, most of which are the arrow-head or bird-track character. These are all cut on the edge of the strata, presenting a face nearly vertical, but a little shelving outward, so as to be sheltered by the weather.

Another copy of the remnants of similar inscriptions was taken by Colonel Whittlesey and Mr. J. B. Comstock, in 1869, from the "Turkey Foot Rock," at the rapids of the Maumee, near Perrysburg. These are on a block of limestone, and in the course of the twenty-five past years have been nearly destroyed by the hand of man. What is left was taken by a tracing of the size of nature.

On the surface of a quarry of grindstone grit at Independence, Cuyahoga County, Ohio, a large inscribed surface was uncovered in 1854. Mr. B. Wood, Deacon Bicknell, and other citizens of Independence, secured a block about six feet by four, and built it into the north wall of a stone church they were then building. Colonel Whittlesey presented a reduced sketch, one-fourth size of nature, taken by Dr. Salisbury and Dr. J. M. Lewis, in 1869, which was made perfect by the assistance of a photographer. Some of the figures sculptured on this slab are cut an inch to an inch and a half in the rock, and they were covered by soil a foot to eighteen inches in thickness, on which large trees were growing. Like all of the others they were made by a sharp-pointed tool like a pick, but as yet no such tool has been found among the relics of the mound-builders or of the Indians. The figures are very curious. Among them is something like a trident, or fish-spear, a serpent, a human hand, and a number of track-like figures, which the people call buffalo-tracks, but Dr. Salisbury regards as a closer representation of a human foot covered by a shoe-pack or moccasin. Another figure somewhat resembles the section of a bell with its clapper.

Near the west line of Belmont County, Ohio, Mr. James W. Ward, then of Cincinnati, now of New York, in 1859, took a sketch of two large isolated sandstone rocks, on which are groups of figures similar to those already noticed. Here are the bird-track characters, the serpent, the moccasin or buffalo-tracks, and some anomalous figures. These are plainly cut, with a pick, into the surface of the rock, which, like the Independence stone, is substantially imperishable. Here we have also the representation of

the human foot, and the foot of a bear. Another figure, which appears to be the foot of some animal with four clumpy toes, Professor Cope thinks may be the foretrack of a Menopome. One peculiarity of these sculptured human feet is a monstrously enlarged great-toe joint, even greater than is produced by the modern process of shoe-pinching. This has been observed in other ancient carvings of the human foot upon the rocks near St. Louis, Missouri. These feet range in size from seven to fifteen inches in length. Of all these representations, the bear's foot is closest to nature. The bird-track, so called, presents six varieties, none of which are anatomically correct. The human hand is more perfect than the foot.

Dr. Salisbury finds, on comparison of these symbolical figures with the Oriental sign-writing, or hieroglyphical alphabets, that there are many characters in common. Some 800 years before Christ, the Chinese had a bird-track character in their syllable alphabet. The serpent is a symbol so common among the early nations, and has a significance so various, that very little use can be made of it in the comparison.

These inscriptions differ materially from those made by the modern red man. He is unable to read that class of them which appears to be ancient.

Lieutenant Whipple has mentioned in the "Government Report on the Pacific Railroad Surveys," an instance of the bird-track character inscribed upon the rocks of Arizona. Professor Kerr, of North Carolina, states that he has noticed similar characters cut in the rocks of one of the passes of the Black Mountains, at the head of the Tennessee River.

These facts indicate wide-spread universality in the use of this style of inscription, and it indicates something higher than the present symbolical, or picture writing, of the North American Indians.

C. PRACTICAL SCIENCE.

1. Improvements upon Eggertz's Method for Determining Combined Carbon in Steel. By Edward R. Taylor, of Cleveland, Ohio.

To relieve myself from the thraldom of monotonous routine work that would otherwise absorb nearly all of my time, the following improvements for the execution of Eggertz's method for determining carbon in steel were devised.

A balance consisting of a very fine thread of glass, with a pan in two parts, one a cup and one a cone, serves to weigh the steel.

A horizontal drill with a glass tube to form a hopper makes and conducts the drillings of steel, as they are made, to the balance pan, which is properly supported about one-eighth of an inch above a point to which it settles, when a two-hundred-milligramme weight is placed in the pan. Being thus set, a sample of steel is placed in the drill lathe, the drillings as before mentioned falling into the pan below. As soon as two hundred milligrammes' weight is in the pan, the pointer sinks to the index, when the drill is stopped. By passing a tube through a hole in the balance table, the lip of the tube offering a support for the balance cup, while the cone is pressed down with a pair of tweezers, the drillings at once fall into the tube, and are ready for treatment with acid.

A glass funnel is made, with a capillary opening, at the contracted lower end. This is fused into a T tube, the lateral branch of which is passed through the window of the laboratory to remove the fumes. A rubber nipple is placed on the lower end of the T tube, into which the tube containing the steel is inserted. Three cc. of nitric acid of 1.2 specific gravity are now drawn into the funnel tube, and fall in drops upon the steel below. At the end of this action, the tube is transferred to a bath kept at the temperature of 130° C. At the end of twenty minutes from drawing in the acid, the operation is completed; the whole of the carbon has entered into a clear yellow solution, which has a depth of color proportionate to the amount of combined carbon in the steel. The tubes are cooled down to a normal temperature, and compared with a

series of standard colors, when it is easy to read off the amount of combined carbon in a given sample of steel. The accuracy and ease of execution of this method leave little to be desired; while it is of great value in ascertaining the amount of carbon in different specimens of steel, or the regularity of its diffusion in different parts of the same cast.

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2. Ancient Dentistry. By Ezra Read, of Terre Haute, Indiana.

Among other arts known to the ancients and extensively used was that of dentistry.

To those of us who have witnessed the growth and almost the beginning of modern dentistry,—for its present perfection has been attained within the last forty years,—it seems curious that it is but the revival of an art which, for seventeen hundred years, had been buried with the ruins that covered up the intellectual greatness of the world.

Tully and Virgil, Horace and Mecænas, and the Triumvirate Cæsars, may have enjoyed the preserving and improving effects of gold filling in their teeth, for Cascellius (a Roman dentist) extracted and repaired them.

Not until Hunter and Bichat of the last century directed attention to diseases of the teeth had modern civilization demanded knowledge upon this subject.

Subsequently to this, and at the close of that period of time, the improvement in the mechanical department of dentistry was slow and unsatisfactory, and so beyond the first third of the present century, when it was quickened into rapid growth by the same mental impulses that hurried steam to machinery, and thought to electricity.

They were contemporaneous in their swift progress, and the art of dentistry was lifted up to that condition in which it had existed nearly five hundred years before the birth of Christ, when gold was used to fill the teeth, and gold wire to bind them fast.

This was evidence of the skill the ancients had attained in mechanical dentistry at that time, as well as the knowledge of metallurgy required in the preparation of the materials used.

The human mind, in its natural order of progression in discovery, would first develop those things most necessary for physical existence; then, those necessary for comfort; and, lastly, those required to gratify the taste, to adorn the person, and to attract admiration. In accordance with this law, dentistry would be developed only after the attainment of advanced civilization. At what period it was first attempted, in what manner developed, and what other materials than gold, if any, were used, I have no means of certainly knowing.

The first reference, by any authority which I have found, recognized it in an advanced state at that time, and, curious enough, it was not mentioned then because it was a new art, but because the sanctity of the grave appealed to the merciful protection of the law against violence to the teeth of the dead which were filled, or bound with gold; for the wicked were tempted then, as now, with the precious metal.

A fragment of the tenth of the twelve Roman tables, which were adopted by the Senate, the Centuries, and the Curiæ B.C. 453 years, relates to the burial of the dead, and provides against the removal of gold from the teeth in the following language:—

"(Mortuo) neve aurum addito cui auro dentes vincti essunt ast eum cum illo sepelire urere sine fraude esto."

Let no gold be placed upon the dead; but where the teeth are bound with gold it is to be buried or burned with the body without injury.

It was the custom of the Romans to remove all gold ornaments from the dead before burial, made so by the above law.

Herodotus, who wrote 450 years B.C., states that the Egyptians were skilful physicians fifteen hundred years before his time, and that they were required by law to confine themselves to the practice of a single branch of the art, and that diseases of the teeth were one of those practised upon. It is a reasonable inference, then, that they extracted and repaired the teeth, and even filled them, when decayed, with some indestructible substance, because they were more learned than other nations, and greatly more advanced in the various arts and sciences. Whatever knowledge they had was transferred to Greece, and thence to Rome, through

the three commissioners sent beyond the sea into Greece to collect such notices of the laws and constitutions of the Grecian States as might be serviceable to the Romans in the reorganization of their own laws.

The Decemvirs availed themselves of this information in framing the Twelve Tables, which continued for hundreds of years to be the foundation of the Roman laws.

A sophist, of Ionia, is said to have rendered valuable assistance to these commissioners in explaining to them the arts, laws, and institutions of his countrymen, and especially of the Athenians, the great glory of the Ionian race.

The fragment of the Twelve Tables relating to the burial of the dead affords abundant evidence of the existence and perfection of the art of dentistry at the time of their adoption. It specified the binding together of the teeth with gold, and then provided that such gold should be buried or burned with the dead body, and that no violence should be offered by attempting to remove it. It was a provision against the violation of the dead for the sake of the gold used by the dentist for the preservation of the teeth. But, added to this, there is other testimony relating to this subject, from those who are recognized throughout the civilized world as standard authorities upon matters of which they write.

Four hundred years before the birth of Christ, Hippocrates spoke of joining the teeth together with gold wire and recommended it in fractures of the jawbone, or where the teeth were loosened by injury or disease: "Dentes inter se conjungere oportet — atque hoc maximè auro." It is proper to join the teeth together, and this should especially be done with gold.

Before that time, seven teeth were found in a Greek tomb united together with gold wire.

Celsus, a distinguished Roman physician, who wrote in the first century, recommended that the decayed part of the teeth should be scraped, or filed off: "Dens autem scaber, qua parte niger est, radendus est."

The hollow part was also cleaned and scraped.

We are informed by the Roman poet, Martial, that the ladies of Rome increased their personal attractions with artificial teeth made of bone or ivory.

> "Sic dentata sibi videtur, Ægle,
> Emptis ossibus, Indicoque cornu." — Mar. Lib. i. Ep. 72.

"So Ægle, with her bought and Indian bone,
May seem to have a sound mouth of her own."

The same author, in his tenth book of Epigrams, says:

"Eximit aut reficit dentem Cascellius ægrum."

"Cascellius extracts or repairs the aching tooth."

Here we have the Roman dentist Cascellius, who "eximit" extracts, if necessary, or "reficit" repairs the diseased tooth, just as is done at the present time.

The same author, in an epigram addressed to tooth-powder, says:

"Quid mecum est tibi? me puella sumat:
Emptos non soleo polire dentes."

"What have I to do with you? Let the fair and young use me. I am not accustomed to polish false teeth," literally, *bought teeth*.

And again, this author mentions teeth which were bought:

"Thais habet nigros, niveos Lecania dentes.
Quæ est ratio? Emptos hæc habet, illa suos:
Dentibus atque comis, nec te pudet, uteris emptis."

"Thais has black and Lecania snowy white teeth, because the former has her own, the latter false teeth, and does not blush to wear bought teeth and hair."

Lucian, of Samosata, who wrote in the beginning of the second century, in his satire upon the complete orator says:

"After this I made up to a rich old dame who, in spite of her seventy years, had still a great liking to handsome young people, pretended a violent passion for her, notwithstanding she had only four teeth, and they were fastened in with gold wire." — Tooke's translation of Lucian, vol. ii., p. 511.

I have thus presented the evidence which I have gathered of the existence of dentistry dating, authoritatively, four hundred and fifty-three years before the birth of Christ, and extending to the end of the first century of the Christian era, a period of nearly five hundred and fifty years. How long before, and how long subsequently to those periods it existed, I have no means of certainly knowing. Its beginning and ending could not have been abrupt; for it is an art, necessarily, of slow growth, and was probably extinguished only when barbarism crushed out the arts and sciences of Greece and Rome.

I have proved by the Twelve Tables that dentistry had a legal recognition four hundred and fifty-three years before Christ.

I have proved that Hippocrates recommended the use of gold wire in binding together loose teeth four hundred years before Christ, and that the Roman physician Celsus practised the art in the first century.

I have shown that it was an art familiar to the great writers of Rome, and that they made frequent intelligent allusions to it, and that the ladies preserved their charms with purchased teeth made from ivory and bone.

It was then, as now, an expensive luxury, and the word, *bought*, implied that it was artificial and that the dentist required pay for his material and skilled labor.

I have proved by Martial that the dentist Cascellius extracted and repaired teeth, and by the same author that tooth-powder disdained to be applied to false teeth.

I have proved by Lucian that an old woman of his time had but four teeth, and that they were held in by gold wire.

This proof extends over a period of nearly six hundred years, and is conclusive as well as additional evidence of the advanced civilization of a people whose arms had subjugated and whose laws governed from the Baltic to the Nile, and from the Atlantic, west to the Euphrates; a government which Dionysius of Halicarnassus declared to be the mistress of every country not inaccessible or uninhabited; that every sea owned her power, not only that within Hercules' Pillars, but also the whole navigable ocean; that she was the first and the only State recorded in history that ever made the east and west the boundaries of her empire, and whose senate was worthy the appellation of an assembly of kings.

It was natural enough that an aggressive people, like the Romans, who never gave back or away a single foot of territory acquired in peace or in war, who had all the learning of the Egyptians and the Grecians, skilled in oratory and poetry and the sciences and useful arts, should have a practical knowledge of dentistry as they had of heating their houses by means of hollow tubes curiously laid in the walls, through which the heat was transmitted simultaneously to every part, from the lowest to the highest equally:

"Et impressos parietibus tubos, per quos circumfunderetur calor, qui ima simul et summa foveret æqualiter." — Seneca, Epis. xc.

or of that other art, short-hand writing, in which they were especially skilled:

"Quid verborum *notas*, quibus quamvis citata excipitur oratio et celeritatem linguæ manus sequitur." — Seneca, Epis. xc.

"Swift though the words the pen still swifter sped,
The hand has finished ere the tongue has said."

It was the *διὰ σημείων* of Cicero written to Atticus concerning the ten legates.

These arts would naturally enough be the result of a thousand years of civilization and national progression, and it has seemed to me, from historical reference, that it requires about that period of time to bring to nearness of perfection human knowledge in the arts and sciences.

The Egyptians had more than this, the Greeks and the Romans had more, and when we shall have added six hundred years to the four hundred already passed, the earth and the seas and the heavens will have given to science their full treasures.

TITLES

OF

COMMUNICATIONS.*

A. MATHEMATICS, PHYSICS, AND CHEMISTRY.

1. QUATERNION NOTATION APPLIED TO THE CO-ORDINATE PLANES. By J. D. WARNER.

2. NOTE ON THE PERIODICITY OF THE SOLAR SPOTS. By DANIEL KIRKWOOD.

3. THE CAUSE OF STELLAR HEAT AND LIGHT. By JACOB ENNIS.

4. ON THE PROBABLE AGE OF HALLEY'S COMET. By DANIEL KIRKWOOD.

5. ON THE DISTRIBUTION OF THE MEAN DISTANCES OF THE MINOR PLANETS. By DANIEL KIRKWOOD.

6. THE RELATION BETWEEN THE DISTANCES AND PROPER MOTIONS OF THE STARS. By T. H. SAFFORD.

7. ON THE RAIN-FALL IN THE UNITED STATES. By JOSEPH HENRY.

8. ON THE USE OF THE BALANCE FOR DETERMINING THE CHANGES IN ATMOSPHERIC PRESSURE, AND THE CO-EFFICIENT OF BAROMETRIC CORRECTION. By P. H. VAN DER WEYDE.

9. REMARKS ON THE SNOW LINE IN THE MOUNTAINS OF MONTANA. By G. C. SWALLOW.

* The following papers were also read; of some, no copy has been received for publication; of others, it was voted that the title only should be printed. No notice, *even by title*, is taken of articles not approved.

10. On the Construction and Verification of Metric Standards for the United States. By J. E. Hilgard.

11. On the Enharmonic Scale of Thirty-one Tones in the Octave, and a New Practical Keyboard corresponding with the accepted Musical Notation. By P. H. Van der Weyde.

12. On True Musical Intonation. By S. D. Tillman.

13. On a New and more Perfect Fire Test of Illuminating Petroleum, without the Use of Fire. By P. H. Van der Weyde.

14. The Character and Chemical Composition of the Meteorite that fell in May near Searsmont, Maine. By J. Lawrence Smith.

15. A New and Ready Method of Making Platinum Black. By J. Lawrence Smith.

16. Remarks on the Cinnabar and other Minerals from California. By J. Lawrence Smith.

17. A Ready Method of Separating the Alkalies, on a Large Scale, from Lepidolite. By J. Lawrence Smith.

18. On Chemical Equivalents. By S. D. Tillman.

19. The Co-relation of Electricity and Chemical Force. By H. F. Walling.

20. On Oblique Microscopic Examination, and a New, Simple Apparatus for the same. By P. H. Van der Weyde.

21. On the Invisible Caloric Extreme of the Solar Spectrum, and the Non-caloric Lines or Bands in the same. By P. H. Van der Weyde.

22. Radiation. By H. F. Walling.

23. On the Transmission of Heat. By S. D. Tillman.

24. Report on Photographing Histological Preparations by Sunlight. By J. J. Woodward.

25. Remarks on a New Form of Achromatic Condenser, applicable to Low and Medium Powers. By Edwin Bicknell.

26. On a New Form of Micro-Telescope. By R. H. Ward.

27. Remarks on Recent Improvements in Achromatic Condensers. By R. H. Ward.

28. On the Use of the Microscope in Chemical Analysis. By P. H. Van der Weyde.

29. On the Observation of the Electric Induction Spark by the Micro-Spectroscope. By P. H. Van der Weyde.

30. On Oblique Microscopic Illumination, and a New, Simple Apparatus for the same. By P. H. Van der Weyde.

31. Remarks on a Standard of Powers for Microscopical Objectives and Eye-Pieces. By R. H. Ward.

32. Clouds and Storms on the Summit of Mount Washington, in the Winter of 1870–71. By J. H. Huntington.

B. NATURAL HISTORY.

1. On some of the Results in Geology and Palæontology of the Geological Survey of Ohio. By J. S. Newberry.

2. The Lignites of the West; their Geology and Economic Value. By J. S. Newberry.

3. On the Gas Wells of Northern Ohio and Western Pennsylvania. By J. S. Newberry.

4. On the Terre Haute Oil Well. By T. Sterry Hunt.

5. On the Mineral Resources of Indiana. By T. Sterry Hunt.

6. On the Common Animals. By E. S. Morse.

7. On the Homologies of the Rays of the Dorsal Fins of Polypterus. By E. D. Cope.

8. Notes on Sedimentary Rocks. By T. Sterry Hunt.

9. Some Observations on the Stratigraphy and Geology of Ohio. By E. B. Andrews.

10. Some Questions on Surface Geology. By Frank H. Bradley.

11. Observations on the Geology, Physical Features, and Retrocession of Niagara Falls. By George W. Holley.

12. On the Geology of North-western Massachusetts. By Sanborn Tenney.

13. Remarks on the Geological Map and Section of Missouri Rocks. By G. C. Swallow.

14. Remarks upon the Catskill Red Sandstone Group as it occurs upon the Borders of New York and Pennsylvania. By James Hall.

15. On Fossils and Minerals from North Carolina. By W. C. Kerr.

16. Note on the Distribution of Population in the United States. By J. E. Hilgard.

17. A Theory on the Nature of the Difference in the Mental Capacity of High and Low Races of Men. By Renas Davis.

18. On the Morphology of the Osseous System. By T. C. Hilgard.

19. Remarks on the Abies Douglassii, and a New Species, or a Peculiar Variety, of the Abies Balsamifera, of the Rocky Mountains. By G. C. Swallow.

20. The Classification of Echinoderms from their Microscopic Structure. By Alexander E. R. Agassiz.

21. On the Embryology of Amblystoma Lurida of Sager. By P. R. Hoy.

22. On Pterosauria. By B. W. Hawkins.

23. An Examination into the Laws of Development of Organic Types. By Edward D. Cope.

24. On the Relation of Anomia. By Edward S. Morse.

25. On the Entozoa peculiar to Swine. By William B. Fletcher.

26. Observations on the Common Ground Worm. By James J. H. Gregory.

27. The Embryology of Chrysopa, and its Bearings on the Classification of the Neuroptera. By A. S. Packard, Jr.

28. Fertilization of Flowers by Insect Agency. By Asa Gray.

29. On some Observed Changes in Verticella. By A. H. Tuttle.

30, On the Microscopic Structure of Eozoön Canadense. By Edwin Bicknell.

31. Notice of Tertiary Insects Found by F. C. A. Richardson on the Green River, in Wyoming. By J. H. McChesney.

EXECUTIVE PROCEEDINGS

OF

THE INDIANAPOLIS MEETING, 1871.

HISTORY OF THE MEETING.

THE Twentieth Meeting of the American Association for the Advancement of Science was held at Indianapolis, Indiana, commencing on Wednesday, August 16, and continuing to Tuesday evening, August 22.

One hundred and ninety-six names are registered in the book by members who attended this meeting. One hundred and seventy-five new members were chosen, of whom one hundred and thirty-eight have already signified their acceptance by paying the entrance-fee and annual assessment, and, when practicable, signing the constitution. One hundred and seven papers were presented, most of which were read, and some of them discussed at length.

The general sessions of the Association were usually held in the State House, where the sections and committees also found ample accommodation. Occasionally, a general meeting convened in the Academy of Music, which afforded accommodation for a larger audience.

At about 10 o'clock, A.M., on Wednesday, the members were called to order by Dr. T. S. Hunt, the retiring president, who made a few appropriate remarks, and then proceeded to complete the organization of the meeting. As soon as the additional members of the Standing Committee had been chosen, agreeably to the provision in the constitution, the Association adjourned, to meet in sections, section B remaining in the hall of general meeting, viz., the House of Representatives, and section A assembling in the

Senate Chamber. After the sections had been organized by the election of Chairman, Secretary, and Sectional Committee, they proceeded at once to the reading of papers.

At 3 o'clock in the afternoon, the formal reception of the Association by the Local Committee took place in the Academy of Music. Prayer was first offered by the Rev. Dr. B. Franklin, and then Governor Baker welcomed the members in the following address: —

MR. PRESIDENT, GENTLEMEN, MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: —

The gentlemen having the arrangements in charge, though not on account of any particular personal merit in myself, have assigned me the pleasing duty of extending to you our welcome to our State and to its capital city. I assure you, gentlemen, that ever since it was announced to our people that the Twentieth Annual Meeting of the American Association for the Advancement of Science would be held in Indianapolis, they have looked forward to this meeting with the deepest interest. We look upon you as the representatives of the most profound thought and of the highest culture of the age in which we live. As such, we cordially welcome you here to-day, in the hope that your stay will be pleasant and profitable to you, as we know that it will be to us. In these few words, gentlemen, I bid you a hearty welcome.

The retiring President, T. S. Hunt, responded in these words: —

It only remains for me, in the name of this Association, to thank your Excellency, and, through you, the people of this State, for this welcome, and to say to you and to the gentlemen here present some few words about the object and work of this Association. It is now about thirty years since a few American naturalists and geologists formed themselves into a society for the study and advancement of science, out of which this Association has since sprung. They met year after year, until the plan of study and scientific inquiry that had been pursued was considered too contracted. They then organized on a new basis, and in 1851 — twenty years ago — the President of the American Association for the Advancement of Science proclaimed its first meeting at Philadelphia, — a meeting at which I was present. I might speak to you of still earlier meetings of which I have pleasant reminiscences, not altogether unprofitable to recall at this time. In the year

1845, a band of men gathered at New Haven, representing, as our Association does now, the best scientific thought and the ablest scientific investigators in the United States. Very few of them do I see to-day; and very few of them are to-day in the land of the living. Four of the brothers Rogers were there, only two of whom are now living. There were Silliman, Rev. Dr. Hitchcock, and a host of others, who, for the most part, are no longer with us. Still we have with us to-day some few representatives of that early meeting; while we have still more of the first meeting of the present Association, which was the successor, the heir, the inheritor of the old one. We have with us Professor Hall, our great geologist and palæontologist, who has contributed so much, not only to the geology and palæontology of his own region, the State of New York, which he has made his own, but also of the great Valley of the Mississippi. We have among us Professor Henry, whose great discoveries in electro-magnetism made the practical use of the electric-telegraph a possibility. We have here also our great botanist, who will to-morrow take the chair which I so unworthily fill to-day.

Without enumerating other names illustrious in scientific annals, I may allude to the labors of scientific investigators in the West in early times. Here in the great North-west, which to us, in the East, at that period was almost *terra incognita*, were to be found great naturalists who brought to us the treasures of their science from the far Western fields, and here in the State of Indiana was to be found the first nursery of Western science. In that colony at New Harmony was early gathered together a band of naturalists who have left an indelible mark upon American science. Among them was William McClure, who was really the pioneer of American geology, and who first attempted the classification of the rocks lying between the Mississippi and the Atlantic. He may justly be claimed as the "Father of American Geology." Among those associated with him were the brothers Owen, one of whom, Richard Owen, we have with us to-day, the venerable representative of that early nucleus of geologists and naturalists, and the only one now living of those men who once made New Harmony illustrious.

The field of investigation that is open before the Western naturalist, is in many respects unlike that in the East. As we come into the Mississippi Valley, our rugged and barren mountains are exchanged for rich and fertile valleys. The flora of this great region offers something entirely distinct from that of our Atlantic

seaboard. Perhaps nowhere else in the world are the Palæozoic rocks, with their characteristic fossil remains, so wonderfully developed as in the limestone of the Mississippi Valley. You know how rich the harvest is that is yielded here to the entomologist and the botanist. It is to this great valley of the Mississippi, so rich in all the elements of material prosperity, that we are to look in years to come for investigators to arise, who shall carry their scientific studies westward into the great Rocky Mountain range, and the country lying between it and the western seaboard.

There are inducements stronger in some respects to scientific investigation in this region than in those regions which lie farther east. In the mountains to the west of us we have great mineral treasures, — treasures which will richly repay the careful investigator in geology and mineralogy, and which promise a far greater and richer harvest than any that we have been able to extract from the Apalachian field. I look, therefore, to this great Mississippi Valley and its vast treasures as being a great material power in commerce and manufactures. But not only so: I also look forward to see here great schools of science, where not only the highest theoretical science shall be taught, but where also we shall have a living science, and where all the practical truth that chemistry and physics have taught us, shall be taught and explained to the students who are hereafter to explore this great West. I trust that before I leave this region I shall have still further opportunities to see what is being done and what is projected in regard to scientific education, here and in other great centres of the West. I could wish that I might be spared to come here twenty-five years hence; in that event, I should expect to find Indianapolis, or perhaps some rival city of the West, a centre where letters, art, and science will be represented on a scale upon which they are nowhere represented in our country to-day. The great natural wealth that centres in this region must eventually make this a point of more importance, scientific and commercial, than any of our Eastern seaboard cities. Indianapolis may well claim to become one of those great centres. I am happy in the reflection that we have many eminent naturalists among us — your own Professor Cox, Owen, and others — who are gathered together here with their hands full of rich treasures to be laid before us during our meeting; and in this we have an earnest, that the scientific traditions of the State of Indiana and the colony at New Harmony are not forgotten.

Again, your Excellency, I thank you, in the name of the Association, for the cordial welcome extended to us. We have already seen the most hospitable disposition on the part of your citizens, and I am confident that, before we close our meeting, we shall have other and warmer reasons to thank you for your kindness.

At the conclusion of Dr. Hunt's speech the meeting was closed with a benediction by Rev. Dr. Franklin.

In the evening, Dr. T. S. Hunt delivered his address as retiring President. At its close he said that his duties as President of the last meeting were finished, and he would introduce Professor Asa Gray, who was to succeed him as President of the Indianapolis meeting.

Professor Gray came forward, and, after expressing the pleasure he had experienced in listening to the interesting and sound address just read by Professor Hunt, returned thanks for the honor conferred upon him in selecting him to preside over the Association.

On Friday morning, the members of the Association, with the ladies in their company, accompanied by many ladies and gentlemen of Indianapolis, made an excursion to Terre Haute, visiting, on their way, the coal mines and furnaces in the vicinity of Brazil. At this prospective Birmingham of the West, they were met and sumptuously entertained by the citizens of Brazil, the ladies of the city taking a conspicuous part in the hospitality so unexpectedly extended to the Association.

The excursionists assembled in Masonic Hall, where the following address of welcome was made by Rev. S. B. Taggart, of the Presbyterian Church: —

MR. PRESIDENT, AND MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: —

On behalf of the citizens of Brazil, it is my grateful duty to say a word of welcome to you, our guests, to-day. Most sincerely do we thank you for the honor conferred on us by this visit. We can only express our satisfaction at seeing the faces of so many representative men from the great Universities, and other centres of learning and thought, from all parts of the Western world.

And though to-day you visit one of the smaller and obscurer towns of a State not famous for its devotion to learning, yet we, as

a people, are far from being uninterested in the work which you pursue, or the institutions which you represent.

These are things that command the homage of all men everywhere. In all labor there is profit, and a busy life is a noble life; but how grand must be the life of that man who bows his head to the toil of extending the horizon of human thought, — for ever dwelling as a frontiersman on the boundary of the unknown!

Gentlemen, we most heartily welcome you to our town, to our homes, to our hearthstones, to all that we have and all that we can do, only hoping that, in the records of this your annual convention, the name of Brazil will stand neither last nor least.

Again we bid you a hearty welcome.

A brief but hearty response was returned by Professor Gray on behalf of the Association, and the guests, who were seated at four long tables placed lengthwise of the hall, and occupying all the body of the room, proceeded without further delay to partake of the ample refreshments set before them.

At Terre Haute, the scientific visitors were most liberally provided for, at the hotels and private houses, and in the evening they had a public reception in the Opera House. A large audience had gathered to greet the strangers, and the audience was called to order by the Attorney-General, Bayless W. Hanna. After a few appropriate remarks, he introduced Colonel R. W. Thompson, to whom the duty had been assigned of extending to the Association the formal welcome of the city. Colonel Thompson spoke substantially in these words: —

For a long time there had not been assigned to him so pleasant a duty as that of extending a cordial welcome to the American Association for the Advancement of Science. In doing this he spoke for our entire community. He welcomed the members of the Association not because they were engaged in the advancement of science, but because we recognized in them great benefactors. Such men as you, said he, have conversed with all the centuries of the past through animal and fossil life; read the heavens, measured the distance from planet to planet, gone down into the waters of the sea, and become familiar with the dwellers therein; seized the lightning, and so tamed it that it speaks both on land and through sea; and have worked out the great problem that Columbus conceived, that the nearest way to the east is by

the west. To our countrymen is to be assigned a fair share of honor for these great results. He claimed that the scientific men of the United States had done more than those of any nation of the world to popularize science. The time will soon come, said he, when a scientific education will be as necessary in our common schools as in the colleges. In conclusion he said: "You come among us strangers, we desire to make you feel at home. You may not see that magnificence to which you are accustomed in the East, but we claim a commendable share of architectural skill."

At the close of the Colonel's address, Professor Asa Gray, President of the Association, responded as follows:—

Accorded such a reception as this — after all that we have seen, and all that has been done for us, gathered in this truly magnificent edifice, and addressed with such consummate eloquence and graphic power, what can this Association say; what can I say for it? The farther west we go, the more astonished we are. But if, for the moment overcome by all we have seen and heard, and are now seeing, we are ready to say, like a noted personage of olden time when similarly astonished by what was shown her, that there is no spirit left in us; yet the heartiness and graciousness of your welcome reassures us, makes us feel at home with you at once, makes it easy for me to say in plain and homely words: —

We thank you heartily: we take real pleasure in accepting your proffered hospitality. We have enjoyed ourselves through the day; we have seen much; we have learned something. Some, like myself new to the West, had a great deal to learn. We have explored your block-coal region; we have seen what your coal will do with iron ore; and we foresee the increase of wealth, population, and all the prosperity it is about to bring you. One of our number will soon say a few words about that. We have been imperially entertained by the Brazilians. We have been refreshed already by your bounteous hospitality. And now we remember that you asked us to come down and do here some of the work of this Association. We are a band of workmen. We work all the year round, and when we come together we find a week full short in which to tell each other what each has gained by scientific labor, how each has improved the talent intrusted to him by our common Lord. Now, refreshed by your hospitality, and encouraged by your sympathy, we propose to set to work.

But first there is a little matter in the internal arrangement of

this society of which I must inform you. You remember how, in regard to the schoolmaster of Goldsmith's village,

> " Still the wonder grew,
> That one small head could carry all he knew."

Our Association early made the discovery that one head cannot carry all it knows. At least the "one small head" that rests upon my shoulders, and is made unduly conspicuous to-day, cannot pretend to carry, still less to tell, all that the Association knows, nor all that it has learned to-day. So the Association has two heads, a retiring President and an incoming President. Now, upon all occasions, and more especially when coal and iron and petroleum are in question, the person who now addresses you is the more retiring of the two. Accordingly he now introduces to you the nominally retiring President, Professor T. Sterry Hunt.

Professor Hunt spoke substantially as follows: —

I shall content myself in saying a few words which may be of some interest to the people of Indianapolis, Knightsville, Brazil, this city, and the State. I shall speak more particularly of the great iron interests, and more especially the manufacture of Bessemer steel. For several years my attention has been turned to that. I have watched the first inception of the manufacture of steel by the Bessemer process with much interest. You are, perhaps, more tributary to England for steel than any thing else.

Many railroad men of this country, including those of the Pennsylvania Central and the New York roads, are seeing the importance of bringing the steel rails into use on their roads. This being the case, then, it is of the highest importance that we have some means of manufacturing the article in our own country. This great result has at length been accomplished by the discovery of block coal in Indiana. Hitherto, the iron ore which is found in this country, in so great abundance, along the banks of Lake Superior, in Minnesota, could not be manufactured into steel without using charcoal, which was too expensive to come into general use. This obstacle, however, has been surmounted by the discovery of block coal between Indianapolis and your own beautiful city, and I do not know any reason why steel rails may not be manufactured in this city by the Bessemer process, in addition to her many other advantages, among which I may include what I heard at Indianapolis, and have realized here, that you have at last struck oil.

From the very first discovery of petroleum in this country, I have been interested in its history, in Pennsylvania and Ohio, along the north shore of Lake Erie in Canada, Chicago, and other places. I believe that, in four square miles under the city of Chicago, is contained as much oil as the wells of Pennsylvania have yielded up to this time. Professor Cox tells me that this oil-bearing limestone is found here in vast quantities. The formation here is such that the probabilities are that your city may prosper and be enriched by bringing it to the surface, while, from the peculiar formation or location of the strata underlying Chicago, it can never be brought to the surface and used to enrich the dwellers therein. May your own fair and beautiful city ever be prosperous in all her interests.

At the close of the retiring President's address, Professor Gray said: —

You now see, ladies and gentlemen, the advantage of our arrangement, and experience the truth of the homely adage that "two heads are better than one." This is one of our merits; let us now take an opposite point of view. We have one notable Vice. The poet says: —

"Vice to be hated needs but to be seen."

But we glory in our Vice, and confidently say of him that

"To be loved he needs but to be seen."

I introduce our Vice-President, Professor Barker.

Professor Barker remarked: —

I, of course, am impressed, wonderfully impressed, more than I can express, with this little city of Terre Haute. I say little, and yet how large it is! — little in size, in population, when compared to some of our larger Eastern cities, *large in its heart*, in æsthetic culture, large in every thing that goes to make a city dear to those who have been there. We are surprised, gentlemen of the Committee, and citizens of Terre Haute, at this grand reception. We are surprised at what we see upon your streets. I really thought, as I came to this hall to-night, that I was "walking down Broadway," if you will allow the comparison.

Your city may some day become the great New York of the West, as New York is characterized the Chicago of the East. It

surprises me, and if you will allow me an allusion to a source which our worthy President has chosen to draw upon, I will say "eye hath not seen, ear hath not heard, nor hath it entered into the heart of man" what the citizens of Terre Haute had prepared for the entertainment of the Association for the Advancement of Science.

After the mutual congratulations were finished, Mr. B. Waterhouse Hawkins delivered a popular lecture "On *Pterosauria* or the Flying Lizard," with felicitous illustrations upon the blackboard.

On Saturday morning a general session was held in the Opera House, and President Gray delivered a lecture "On the Fertilization of Plants by Insects." In the afternoon the members returned to Indianapolis.

In order to make good the large amount of time required for this long excursion, evening sessions were held by the sections, in addition to those of the forenoon and afternoon. On Saturday evening, Professor E. S. Morse delivered a lecture in the Academy of Music "On the Animals of Indiana," and T. S. Hunt spoke at the same place on Monday evening upon the "Iron Interests of Indiana."

The Association voted to hold its next meeting at San Francisco, Cal. (if economical arrangements could be made for transportation and hotel accommodations), beginning on Monday, August 5, 1872; otherwise at Dubuque, Iowa, beginning Wednesday, August 21. The officers elected for the next meeting are: —

Prof. J. LAWRENCE SMITH, of Louisville, Ky., *President;* Prof. ALEXANDER WINCHELL, of Ann Arbor, Mich., *Vice-President;* Prof. EDWARD S. MORSE, of Salem, Mass., *General Secretary;* W. S. VAUX, Esq., of Philadelphia, *Treasurer.* Prof. JOSEPH LOVERING, of Cambridge, was elected *Permanent Secretary* for another term of two years, commencing with the next meeting.

RESOLUTIONS ADOPTED.

Offered by Professor Alexander Winchell.

Resolved, That a committee of five be appointed, to report at the next meeting of the Association, on the best methods of organizing and conducting State geological surveys, and making publication of the results.

Offered by Professor T. S. Hunt.

Resolved, That the important changes going on in the surface-geology of Niagara Falls are such that it is highly desirable that a re-survey of the Falls should be made, the old monuments restored, new ones erected, and large photographs of the locality taken; and, further, that in pursuance of this plan the Legislature of New York be memorialized to order such a survey to be made.

Offered by Professor James Hall.

Whereas, This Association has learned with regret that the greater part of the geological explorations and surveys made in Missouri by Professor G. C. Swallow and his assistants remains unpublished; and,

Whereas, From the general exposition of the results made by Professor Swallow, this Association is convinced of the great value of the work, which should be published as soon as practicable; therefore, be it

Resolved, That the President appoint a committee to memorialize the Legislature of Missouri on the subject, recommending that means be provided for the speedy publication of the results, under the superintendence of Professor Swallow, who had charge of the work, and who, being conversant with its details, is especially fitted to elaborate the results.

VOTES OF THANKS.

Resolved, That we tender our hearty thanks to those citizens of Indianapolis who have extended the hospitalities of their homes to the members of this Association during the present meeting, and to the proprietors of the "Daily Journal" for the proffer of a social entertainment.

Resolved, That the thanks of this Association be tendered to the Governor and State officers of Indiana, for granting to this Association the use of the State House for this meeting, and to the authorities of the city of Indianapolis, for the generous aid given by them toward defraying the expenses of the meeting.

Resolved, That the cordial thanks of the Association be tendered to Professor E. T. Cox, for his exertions in making arrangements for this meeting, which have been so successful as to leave nothing to be desired.

Resolved, That we tender the hearty thanks of the Association to the officers of the Terre Haute, Vandalia, and St. Louis Railroad, for their generosity in placing a special train at the disposal of the Association during their visit to Terre Haute.

Resolved, That the thanks of the Association be presented to the citizens of Terre Haute, and particularly to their efficient committee of arrangements, for their cordial reception and liberal hospitality during their late excursion; also to those residents of Knightsville and Brazil who so bountifully provided for the wants of the members, while *en route*.

Resolved, That the thanks of this Association are most cordially tendered to the officers of the Indianapolis, Peru, and Chicago Railway, and the Michigan Central Railroad Companies, for their appreciation of the objects of the Association, as evinced by their placing a special train at the disposition of a portion of the members in coming to this meeting.

Also, to Captain E. Bennett, United States Engineer, Michigan City, for his kind attentions to the members there; and to the citizens of Michigan City and Kokomo for their cordial attentions to the members on their journey to this city.

Resolved, That the thanks of this Association be tendered to the Jeffersonville, Madison, and Indianapolis Railroad Company for their generous offer of free transportation over their road to all its members; to the New Albany Society of Natural History for their kind invitation to visit them, and to the citizens of New Albany for the proffer of their open-hearted hospitality.

Resolved, That the thanks of the American Association for the Advancement of Science be tendered to the officers of the Louisville and Nashville Railroad for their generous liberality in transporting our members to Mammoth Cave, and also to the proprietors of the hotels at Cave City and Mammoth Cave for their kindness in reducing the expenses of members claiming their hospitality.

Resolved, That the thanks of this Association be given to the newspaper press, and to its reporters and correspondents, for the interest shown in our scientific labors and for the publication of our sayings and doings.

Resolved, That the thanks of the Association be given to the President and General Secretary for the able discharge of their respective duties.

Resolved, That the thanks of the Association be presented to the citizens of Leavenworth for their cordial invitation to hold the next meeting in that city, and to express to them the regrets of the members that the invitation was received too late for action.

Resolved, That the thanks of the Association be returned to the authorities of the city of Pittsburgh for their cordial invitation to hold the next meeting in that city.

After the adjournment of the Association, on Wednesday morning, August 23, nearly two hundred members of the Association and their friends made an excursion to Louisville, Cave City, and the famous Mammoth Cave. Free transportation by railroad, and a generous repast on the way, in the cars, were provided by the kindness of citizens of Louisville, and the railroad authorities. After a successful exploration of the Mammoth Cave, the members of the Association scattered to their homes, a few going out of their way to visit the Wyandotte Cave, and others, by invitation of citizens of Merom, to examine the ancient mounds on the Wabash.

REPORT OF THE PERMANENT SECRETARY.

The following report comprises the business which has been done for the Association during the interval between the first day of the Troy Meeting (August 17, 1870), and the first day of the Indianapolis Meeting (August 16, 1871).

An unusually large number of copies of the Salem volume of Proceedings has been distributed to members. The list of Foreign Academies to which the Proceedings are sent is increased every year. The Troy volume was ready for distribution on the first day of the present month, and will be sent by mail, *prepaid*, to all entitled to receive it. The delay proceeds, partly from the necessity of sending proof-sheets over the whole country, some of which may not find the authors at home; and partly, from the neglect of authors to furnish a copy of their papers, at an early date, for publication. Many valuable papers are not sent at all, and some arrive too late even for the requirements of the slowly printed volume.

The financial condition of the Association is as follows:—

Between August 17, 1870, and August 16, 1871, the income of the Association was eighteen hundred and ninety-nine dollars ($1,899).

Of this amount forty-three dollars and fifty-cents ($43.50) accrued from the sale of the printed Proceedings, and the remainder from the admission fees and the annual assessments.

The expenses of the Association, during the same interval, amounted to twenty hundred dollars and forty-two cents ($2,000.42), which may be apportioned thus:—

Cost of paper, printing, and binding for the volume of Troy Proceedings, and expense of its distribution	$1,361.82
Charges connected with the Troy Meeting	105.00
Salary of the Permanent Secretary (five hundred dollars)	500.00
For circulars, postage, stationery, express, &c.	33.60

The particular items may be found in the cash account of the Secretary, which is herewith submitted as a part of his report. The balance in the Treasury of the Association, August 16, 1871, is sixteen hundred and forty dollars and sixty cents (1,640.60).

JOSEPH LOVERING,
Permanent Secretary.

INDIANAPOLIS, August 16, 1871.

CASH ACCOUNT OF THE PERMANENT SECRETARY.

DR. AMERICAN ASSOCIATION *in account with* JOSEPH LOVERING. CR.

J. W. Harris's Bill as Assistant Secretary	$30.00	Balance from last Account	$1,742.02
Postage	65.00	From Assessments, and Sale of Proceedings (see No. 896 to No. 1000 inclusive, and 1 to 289, inclusive of Cash Books)	1,899.00
Express	1.88		
Printing Circulars	7.50		
Stationery	11.60		
Composition and Press-Work of Troy Proceedings	1171.11		
Paper for Cover	5.75		
Binding	52.13		
Wood-cuts	80.50		
Salary of Permanent Secretary	500.00		
Expenses of Indianapolis Meeting	75.00		
	$2,000.42		
Balance to next Account	1,640.60		
	$3,641.02		$3,641.02

STOCK ACCOUNT OF THE PERMANENT SECRETARY.

Volumes Distributed or Sold, since the Report in Vol. XIX.

VOLUMES.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.
Distributed to Members*														2	5	14	46	457	428
Harvard College																			1
Boston Public Library																			1
American Academy																			1
Boston Nat. Hist. Society																			1
Connecticut Academy of Science																			1
Yale College																			1
Brown University																			1
Boston Athenæum																			1
Smithsonian Institution																			1
Peabody Academy of Science																			1
Foreign Societies†																			78
Sold (this year and last)	4	1	3	2	2	3	2	1	2	2	1	2	3	2	2	5	28	14	
Total	4	1	3	2	2	3	2	1	2	2	1	2	3	4	7	19	74	471	511
Balance, August, 1871	40	94	229	214	416	274	512	834	985	875	809	980	989	1112	571	456	490	850	
Received from Binders																			931
Balance, May, 1872	36	93	226	212	414	271	510	833	983	873	808	928	986	1108	564	437	416	379	420

* Omitted, accidentally, in the last volume.

† See pages 437-8.

LIST OF EUROPEAN INSTITUTIONS TO WHICH COPIES OF VOLUME XIX. OF THE PROCEEDINGS OF THE AMERICAN ASSOCIATION WERE DISTRIBUTED BY THE PERMANENT SECRETARY IN 1871.

Stockholm, —Kongliga Svenska Vetenskaps Akademien.
Copenhagen, — Kongel. danske Vidensk. Selskab.
Moscow, — Société Impériale des Naturalistes.
St. Petersburg, — Académie Impériale des Sciences.
" " Kais. Russ. Mineralogische Gesellschaft.
" " Observatoire Physique Centrale de Russie.
Pulkowa, — Observatoire Impériale.
Amsterdam, — Académie Royale des Sciences.
" Genootschap Natura Artis Magistra.
" Zoölogical Garden.
Haarlem, — Hollandsche Maatschappij der Wettenschappen.
Leyden, — Musée d'Histoire Naturelle.
" The University Library.
Utrecht, — Institut Royal Météorologique des Pays-Bas.
Altenburg, — Naturforschende Gesellschaft.
Berlin, — K. P. Akademie der Wissenschaften.
" Gesellschaft für Erdkunde.
Bonn, — Naturhist. Verein der Preussisch. Rheinlandes, &c.
Breslau, — K. L. C. Akademie der Naturforscher.
Brünn, — Naturforschenden Vereins.
Dresden, — K. L. C. Deutsche Akademie der Naturforscher.
Franckfurt, — Senckenbergische Naturforschende Gesellschaft.
Freiburg, — Königlich-Sächsische Bergakademie.
Göttingen, — Königl. Gesellschaft der Wissenschaften.
Hamburg, — Naturwissenschaftlicher Verein.
Hannover, — Die Naturhistorische Gesellschaft.
Königsberg, — Königliche-Physikalish Okonomischen Gesellschaft.
Leipsic, — Königlich-Sächsische Gesellschaft der Wissenschaften.
Munich, — K. B. Akademie der Wissenschaften.
Prag, — K. Böhm. Gesellschaft der Wissenschaften.
Stuttgart, — Verein für Vaterländische Naturkunde.
Vienna, — K. Akademie der Wissenschaften.
" K. K. Geographischen Gesellschaft.
" Geologischen Reichsanstalt.
" Osterreichische Gesellschaft für Meteorologie.

Vienna, — K. K. Zoologisch-Botanische Gesellschaft.
„ Verein zur Verbreitung Naturwissensch. Kentnisse.
Württemburg, — Der Verein für Vaterländische Naturkunde.
Basel, — Naturforschende Gesellschaft.
Bern, — Allgemeine Schweizerische Gesellschaft.
„ Naturforschende Gesellschaft.
Genève, — Société de Physique et d'Histoire Naturelle.
Lausanne, — Société Vaudoise des Sciences Naturelles.
Neuchatel, — Société des Sciences Naturelles.
Zurich, — Naturforschende Gesellschaft.
Bruxelles, — Académie Royale des Sciences, &c.
Liege, — Société Royale des Sciences.
Cherbourg, — Société Académique.
Dijon, — Académie des Sciences, &c.
Lille, — Société Nationale des Sciences, de l'Agric., et des Arts.
Montpelier, — Académie des Sciences et Lettres.
Paris, — Institut de France.
„ Société Philomatique.
„ Société Météorologique de France.
Turin, — Accademia Real delle Scienzie.
Rome, — Osservatorio Astronomico del Collegio Romano.
Madrid, — Real Academia de Ciencias.
Cambridge — Cambridge Philosophical Society.
Dublin, — Royal Irish Academy.
Edinburgh, —Royal Society.
Liverpool, — The Literary and Philosophical Society.
London, — Board of Admiralty.
„ East India Company.
„ Museum of Practical Geology.
„ Royal Society.
„ Royal Astronomical Society.
„ Royal Geographical Society.
„ Royal Institution of Great Britain.
Manchester, — Literary and Philosophical Society.
„ Natural Hist. Soc. of Northumberland, Durham, &c.
Newcastle-upon-Tyne, — The Tyneside Naturalist's Field-Club.
Oxford, — Radcliffe Observatory.
Batavia, — Société des Arts et des Sciences.

REPORTS.

On Uniformity of Nomenclature in Regard to Microscopical Objectives and Oculars. By R. H. Ward, of Troy, N.Y.

The equivalent focal length of an achromatic objective is universally employed in this country and England, and largely elsewhere, as the name of the objective. Being more significant, and capable of becoming a universal nomenclature, it is manifestly better than the arbitrary naming by letters or numbers at the caprice of individual makers. Yet the carelessness or the ambition of makers has led to a great variation in lenses of identical name, which is familiarly known and is undisputed, a one-fourth inch objective by one maker often being lower than a four-tenths by another maker, or higher than a one-fifth by another. The time has doubtless arrived for a reconsideration of this subject, naming according to some accepted standard all new objectives, and renaming, by the same standard, many of those now in use. We do not ask the opticians to make all their combinations of certain conveniently graded powers, but we do propose so to name our objectives, if we can, that each number shall group together those powers of which it is the nearest and best description.

An accurate method of determining the amplifying power of an objective is to measure the image of a known object (say a stage micrometer) on a screen, at a distance of several feet; but this method requires too many appliances and too much skill to be universally applicable. Every microscopist may measure his objectives as they are actually used in the microscope, by means of an ocular micrometer. Of course the field-lens is removed if a negative ocular is employed. Thus the image is measured directly by the ocular micrometer, at the standard distance of ten inches, a positive ocular, or the eye-lens of a negative one, being used as a simple microscope with which to read off the measurement.

The optical centre of the modern objective being a movable point, and not easily determined at any time, it is a difficult question from what part of the objective the standard distance of measurement, ten inches, is to be measured. Mr. Charles R. Cross

has proposed to measure the ten inches between the conjugate foci used, without regard to the position of the objective; but this plan, sufficiently accurate with high powers, would greatly misrepresent a three-inch objective, and could not measure a four-inch at all. If we measure from the space between the middle and lowest combination of lenses in the objective, or even from the bottom of the whole arrangement, the error will be scarcely, if at all, appreciable, and will be certainly unappreciable if the image be measured on a screen at a distance of several feet.

The screw-collar adjustment for cover-glass is another difficult complication of the question of powers. Most opticians rate the angular aperture at its highest point, but many name the same lenses by their power at its lowest point. It would seem that both angle and focus should be stated at the same point of adjustment, whether the highest or the lowest or an average point be adopted. There seems to be no principle on which a maker can fairly name his angular apertures at their highest point, and then charge with exaggeration those who name their magnifying powers in the same manner. Nowhere do we want to agree upon a uniform usage more than here. In important cases it might be well to give both extremes, or else to state the angle and power at which the combination was worked to accomplish the results specified.

Where an extra front of different properties is added, we have essentially another objective whose power and angle should doubtless be separately stated.

Having agreed upon the amplifying power, it is worthy of consideration whether we should name the objective by this alone, thus expressing conveniently various degrees of power, the present one-inch lens becoming No. 10, or $\times$ 10, or in some cases $\times$ 9 or $\times$ 11; or by its power when combined with some standard (say two-inch) ocular, the one-inch lens becoming No. 50 or $\times$ 50, &c., as above; or, as heretofore, by equivalent focal length. If the focal length is preferred, it would be most easy and unmistakable to assume $\times$ 10 as a one-inch power, and rate other powers in proportion; then this power, ten, divided by the ascertained power of any objective or ocular would give the equivalent focal length of that objective or ocular without comparison and beyond dispute. There would be much advantage, however, in recording the exact amplifying power, either as the name of the lens, or as an additional item (in parenthesis) which should give greater definiteness and accuracy.

The eye-pieces, better called oculars, have been made without any pretence of uniformity, and named without any serious attempt at significance; yet it would seem convenient and proper that they should be so named as to express their magnifying power. This has been done by many microscopists, on a basis of one inch to ten diameters, discarding the letter nomenclature (*A*, *B*, *C*, &c.), and giving the names 2-in., 1½-in., 1-in., $\frac{8}{10}$-in., $\frac{2}{3}$-in., ½-in., $\frac{4}{10}$-in., ⅓-in., and ¼-in., to the oculars nearest the powers of 5, 7½, 10, 12½, 15, 20, 25, 30, and 40; and the writer is satisfied, by experience of its convenience, that this nomenclature needs only a trial to secure its adoption by all those who use the microscope for other purposes than amusement. Of course, any microscopist, having determined the power of an objective, and the powers of the microscope when that objective is used with his various oculars, can obtain the powers of his oculars by dividing the latter numbers by the one first named, and can then name his oculars, like the objectives, either by their magnifying powers or by their equivalent focal lengths.

In reviewing this subject, the following points would seem to be reasonably well settled. Objectives should be, and could be to a much greater extent than they now are, rated according to a uniform standard. They should be named not arbitrarily, but in a manner indicative of their magnifying power. Ten inches is the standard distance of measurement in estimating powers. This distance should be taken from the eye to the rule by which the measurements are made, without regard to the distance of the object on the stage. Magnifying power is always stated in linear measure. The magnifying power and angular aperture, as well as the maker's name, should be engraved on all objectives, and added to all particularly important drawings made by their means. Oculars should be named, like the objectives, in such manner as to indicate their magnifying powers, either directly or by means of their equivalent focal lengths.

The following are some of the more important queries which still remain open. Should the standard one-inch objective be characterized by magnifying ten diameters as used in the compound microscope (with standard length of tube so as to bring the diaphragm of the ocular ten inches from the lower part of the objective), or should it be compared to a simple lens of actually measured focus or foci? Should the objective (and the ocular) be named by its equivalent focal length, or by its amplifying

power, or both? Should our standard distance of measurement, as a concession to the excellence of the metric system, be changed (with scarcely appreciable difference in results) from ten inches (254 millimetres) to nine and five-sixths inches (250 millimetres)? From what point in the objective shall the distance to the scale be measured? At what point of screw-collar adjustment shall the objective be placed for rating its angular aperture and amplifying power? Should the name "ocular" be substituted for "eye-piece" in general use?

Report on the Pacific Railroad Observatory.

The committee reported the following Memorial, soliciting the aid of the Government of the United States: —

To the Honorable the Senate and House of Representatives of the United States in Congress assembled: —

At the meeting of the American Association for the Advancement of Science, held at Troy, in August, 1870, the undersigned were appointed a committee charged with the duty of representing to Congress "the importance of establishing an observatory and maintaining a scientific corps, for a year or more, at one of the highest points of the Pacific Railroad, and particularly at the eastern rim of the Utah Basin."

The committee therefore beg leave to bring to your attention the fact that, for observations having reference to physical astronomy, it is of the greatest importance that they should be as free as possible from the effects of atmospheric interference. When the best optical means for penetrating celestial space are provided, they should be employed at the greatest attainable elevation, consistent with the maintenance of the observers, in order that the phenomena observed with the telescope, noted by photography, or analyzed by the spectroscope, may be in the least degree affected by the want of perfect transparency of the atmosphere or by the cloudiness due to the vapors it holds in suspension.

At the highest point of the Pacific Railroad, nearly one-third of the atmosphere is below the observer, and consequently the great

brilliancy of the stars and transparency of the air have arrested the attention of the traveller.

In addition to the observation of celestial phenomena, the position above mentioned would be highly important for observations relative to the normal direction of the wind over the continent, the diminution of temperature with elevation, and the fitful variations of terrestrial magnetism.

In order to institute a trustworthy comparison between observations made under such conditions and those made near the sea level, and to obtain at least some of the leading phenomena as presented at such an elevation, it is now proposed that the means be provided for establishing an experimental observatory and maintaining a corps of observers for two years. The building need not be expensive, shelter for the instruments and quarters for the observers being all that is required.

The committee would therefore respectfully recommend that the appropriation of $15,000 be made for the purpose set forth, and that the same be intrusted to the Superintendent of the United States Coast Survey.

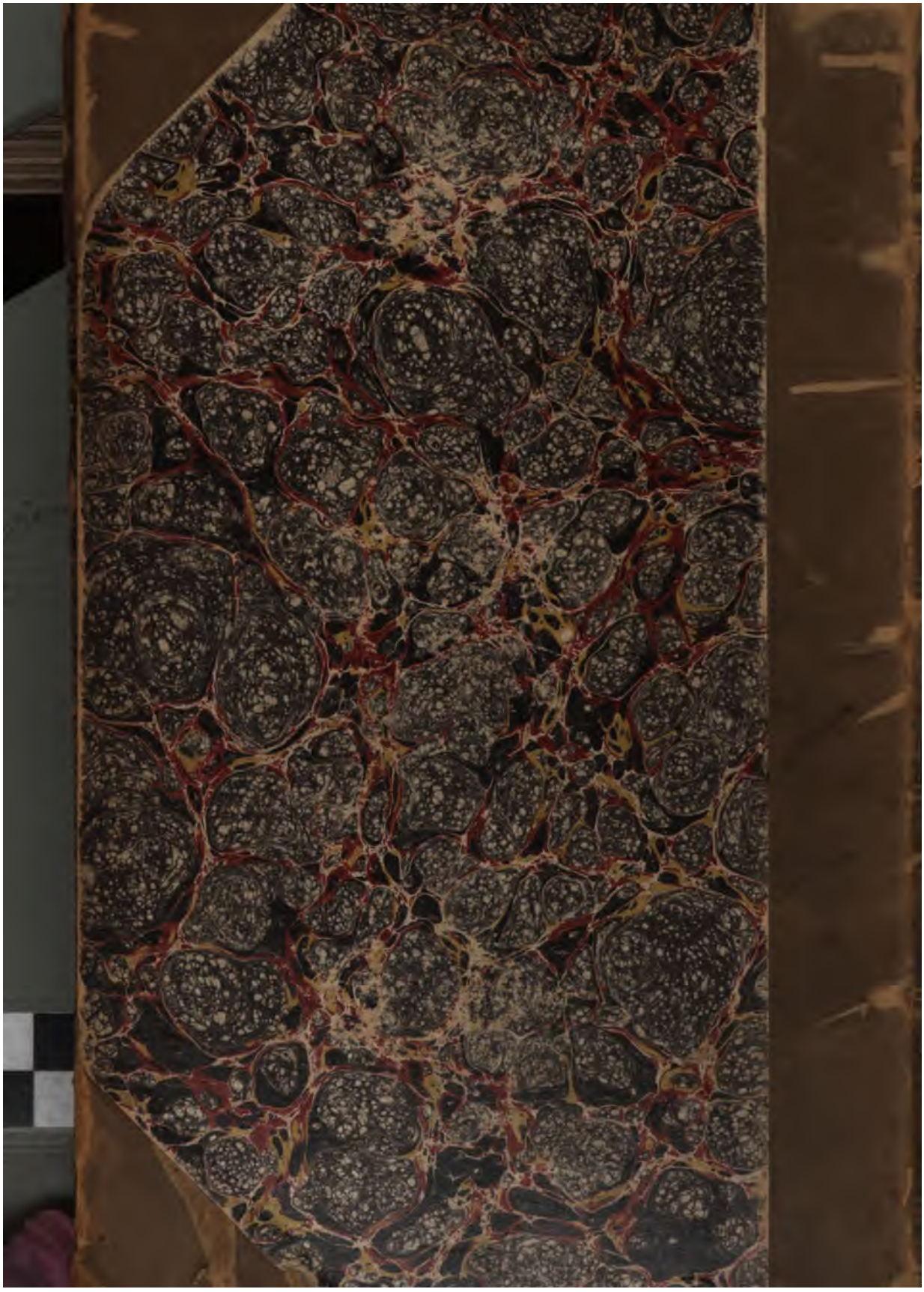
J. E. HILGARD, U. S. Coast Survey.
JOSEPH HENRY, Smithsonian Institution.
JAMES H. COFFIN, Lafayette College, Pa.

Committee of the American Association for the Advancement of Science.

ERRATA.

Soon after the paper, relating to the "U. S. Coast Survey Longitude Determinations across the Continent" had been printed, the Permanent Secretary was informed by Mr. Dean, that the corrections for personal equations had inadvertently been applied to the longitude results, with the wrong algebraic sign.

The following corrected longitude results are therefore printed.

STATIONS.	Difference of Longitude. (λ)	Personal Equation.	Corrected Difference of Longitude.	Probable Errors.
	h. m. s.	*s.*	*h. m. s.*	*s.*
Cambridge to Omaha . .	1.39. 15.159	—.130	1.39. 15.029	±.008
Cambridge to Salt Lake .	2.43. 4.257	—.110	2.43. 4.147	±.008
Omaha to Salt Lake . .	1. 3. 49.081	+.020	1. 3. 49.101	±.008
Cambridge to San Francisco	3.25. 7.260	+.070	3.25. 7.330	±.007
Omaha to San Francisco .	1.45. 52.094	+.200	1.45. 52.294	±.010
Salt Lake to San Francisco	0.42. 3.024	+.180	0.42. 3.204	±.008

On page 386, fourth line from bottom of page, for *Pinus Lembra* read *Pinus Cembra*.